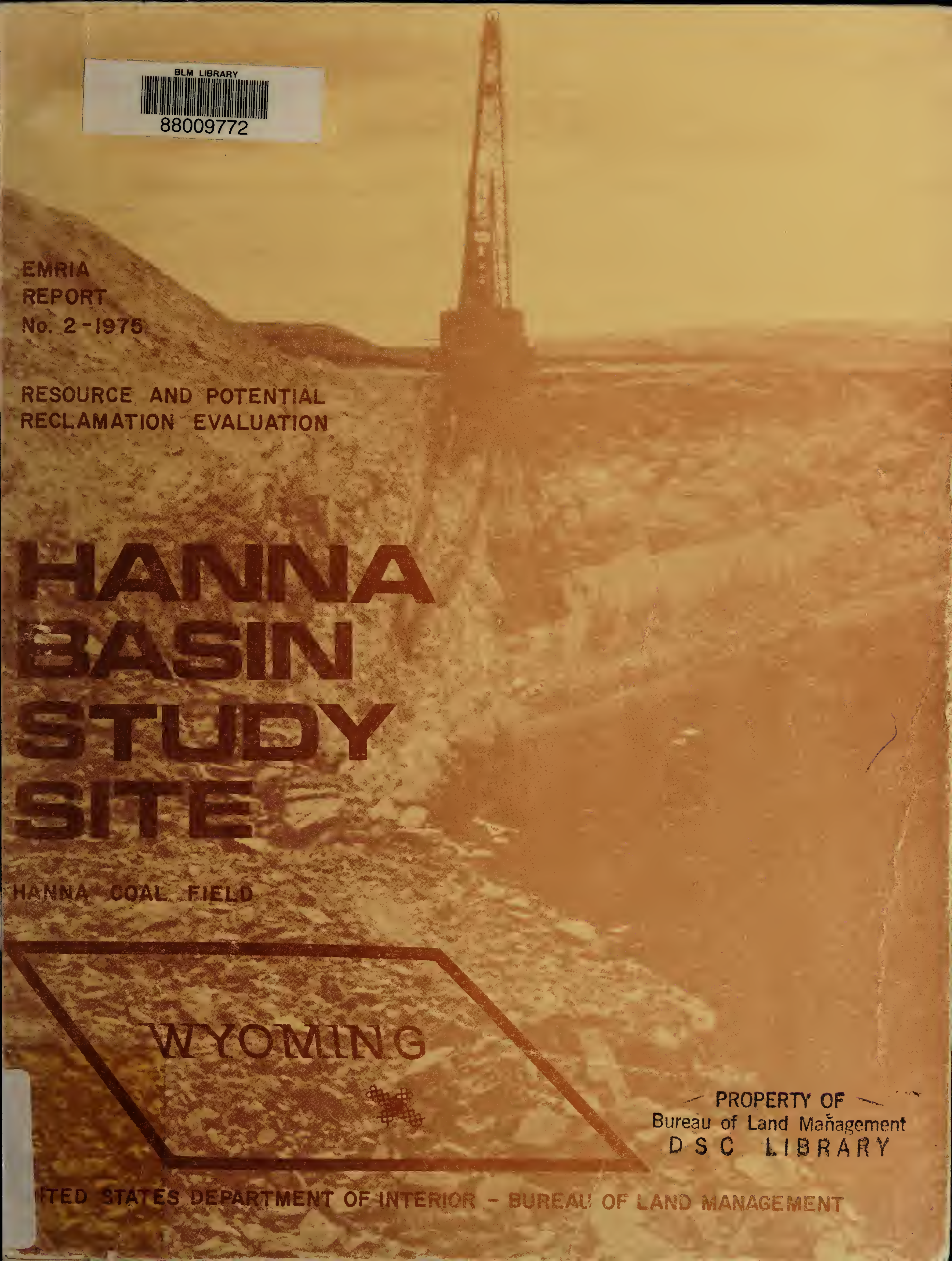

EMRIA
REPORT
No. 2-1975

RESOURCE AND POTENTIAL
RECLAMATION EVALUATION

HANNA BASIN STUDY SITE

HANNA COAL FIELD

WYOMING

ITED STATES DEPARTMENT OF INTERIOR - BUREAU OF LAND MANAGEMENT

EMRIA - Energy Mineral Rehabilitation Inventory and Analysis

EMRIA is a coordinated approach to field data collection, analysis, and interpretation of soil, water, overburden and energy resource data. The main objective of the effort is to assure adequate baseline data for choosing reclamation goals and establishment of lease stipulations through site-specific preplanning for surface mining and reclamation.

These reports are prepared through the efforts of the Department of the Interior principally by the Bureau of Land Management, Bureau of Reclamation and Geological Survey. Assistance is also provided by other Federal and State agencies.

Reports under this effort are:

EMRIA Report	Location	Source - BLM Offices
#1 - 1975	Otter Creek near Ashland, MT	Montana State Office Federal Building 316 N. 26th Street Billings, MT 59101
#2 - 1975	Hanna Basin near Hanna, WY	District Office 1300 Third Street P. O. Box 670 Rawlins, Wyoming 82301
#3 - 1975	Taylor Creek near Craig, CO	Colorado State Office 1600 Broadway - Room 700 Denver, Colorado 80202
#4 - 1975	Alton near Kanab, UT	Utah State Office Federal Building 125 South State P. O. Box 11505 Salt Lake City, Utah 84111

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INTRODUCTION

A growing and affluent society is creating an ever increasing need for energy. Attention has focused on the energy fuels and sources existent in the western states primarily the Rocky Mountain and the Northern Great Plains Coal Provinces due to the abundance, simplicity of extraction, and the high quality of the resources present.

It is the responsibility of the Bureau of Land Management to encourage and assist in meeting these energy demands and at the same time provide sound reclamation and rehabilitation guidelines so that the lands subjected to disturbance are returned to a productive and useful state.

Purpose

The main purpose of this study is to assure the collection of adequate baseline data for choosing optimum reclamation and rehabilitation objectives and for establishing appropriate data and interpretations for preparation of lease stipulations through site-specific pre-planning for mining and reclamation.

Objectives

The overall objectives of the Energy Minerals Resource Inventory and Analysis (EMRIA) program are as follows:

1. To analyze and quantify environmental effects of surface mining of energy minerals (Colorado, Montana, New Mexico, North Dakota, Utah and Wyoming).

2. To provide resource and impact information for the leasing site selection procedures as set forth by the Secretary of the Interior.

3. To provide environmental resource information needed to implement effective reclamation and rehabilitation programs and for the development of meaningful lease stipulations as required by the mined land reclamation program.

4. To provide resource and impact information to support state and local regional development and land use planning efforts.

5. To determine the present and potential capability of the surface soil and subsurface resources to produce and maintain vegetation on known energy fuel deposits.

6. To provide physical and chemical data from which realistic stipulations may be prepared for energy mineral exploration, mining, and reclamation plans.

7. To provide data needed in the preparation of Technical Examination, Environmental Analysis Records, Environmental Impact Statements, and to aid in the review of mining and reclamation plans for proposed land disturbing activities in the vicinity of the study.

Authority

Public Land Administration Act of July 14, 1969, (74 STAT. 506).

Responsibility - (Bureau of Land Management)

1. Select reclamation study site areas for coordinated investigation of vegetation, soil, geological structure, surface water, and ground water.

2. Acts as Contracting Officer in the coordination, establishment, and execution of work orders.

3. Reviews and consolidates work order and field office data and prepares input to reports published by the Bureau of Reclamation.

4. Procurement of easements and rights-of-way to conduct the studies.

5. Distributes technical data, reports, and reclamation and rehabilitation recommendations to Bureau of Land Management field offices.

Responsibility - (Bureau of Reclamation)

1. Conducts soil studies.

2. Conducts drilling operations for the procurement of core samples to be used for the analysis of geological strata in overburden materials.

3. Installs casing in holes selected for ground water observation wells.

4. Characterizes and interprets data available on soils and overburden materials as well as substrata immediately below the coal resources in relation to reclamation and revegetation.

5. Conducts greenhouse studies for determining overburden materials potential for supporting vegetative growth.

6. Conducts weathering tests on core samples to determine stability of overburden materials.

7. Advises and recommends suitable plant species for use in areas to be reclaimed.

8. Advises and recommends reclamation techniques.

9. Prepares a geologic map.

Responsibility - (Geological Survey)

1. Conducts vegetation and soil studies which will result in vegetation maps and related soil characteristics.

2. Assesses reclamation potential based on water available from precipitation.

3. Prepares sediment yield maps.

4. Prepares erodibility maps.

5. Determines rainfall-runoff relationships and chemical quality of surface and subsurface waters.

6. Coal sections and well logs.

7. Coal bed maps showing coal resources.

8. Tabulation of coal resources estimates.

9. Table of analytical results on coal resources.

10. Graphic presentation of analytical results.
    a. Vertical - Plotted against well logs.
    b. Horizontal - Plan view if significant.

11. Evaluation of the effects of mining on the area hydrology and downstreams.

GENERAL DESCRIPTION

The Hanna Basin Study Site is located in the south central portion of the state of Wyoming in Carbon County approximately 35 miles northeast of Rawlins. It is comprised of 2400 acres of national resource lands described as follows:

S½ Section 30 T24N R83W
E½ E½ Section 36 T24N R84W
All Section 32 T24N R83W
All Section 12 T23N R84W
All Section 6 T23N R83W

The site is shown on location map, plate 1, and in more detail on the 7½-minute quadrangles appended. The lands in this area are primarily used for livestock grazing, support of wildlife and coal production. There are no permanent residents, urban-suburban, or commercial developments in the specific study area. The land ownership is within what is commonly referred to as the "checkerboard lands." This is the result of alternate sections being patented to the Union Pacific Railroad in the mid 1800's. Much of this railroad land has since been sold to private individuals who use them in conjunction with the national resource lands for livestock grazing. The coal resources are federally owned.

Underground coal mining began at Hanna in 1888 to fuel Union Pacific locomotives. Strip mining began in 1937. There are at present three active mines in the area producing approximately 7 million tons of coal annually. This represents roughly 50 percent of Wyoming's current coal production.

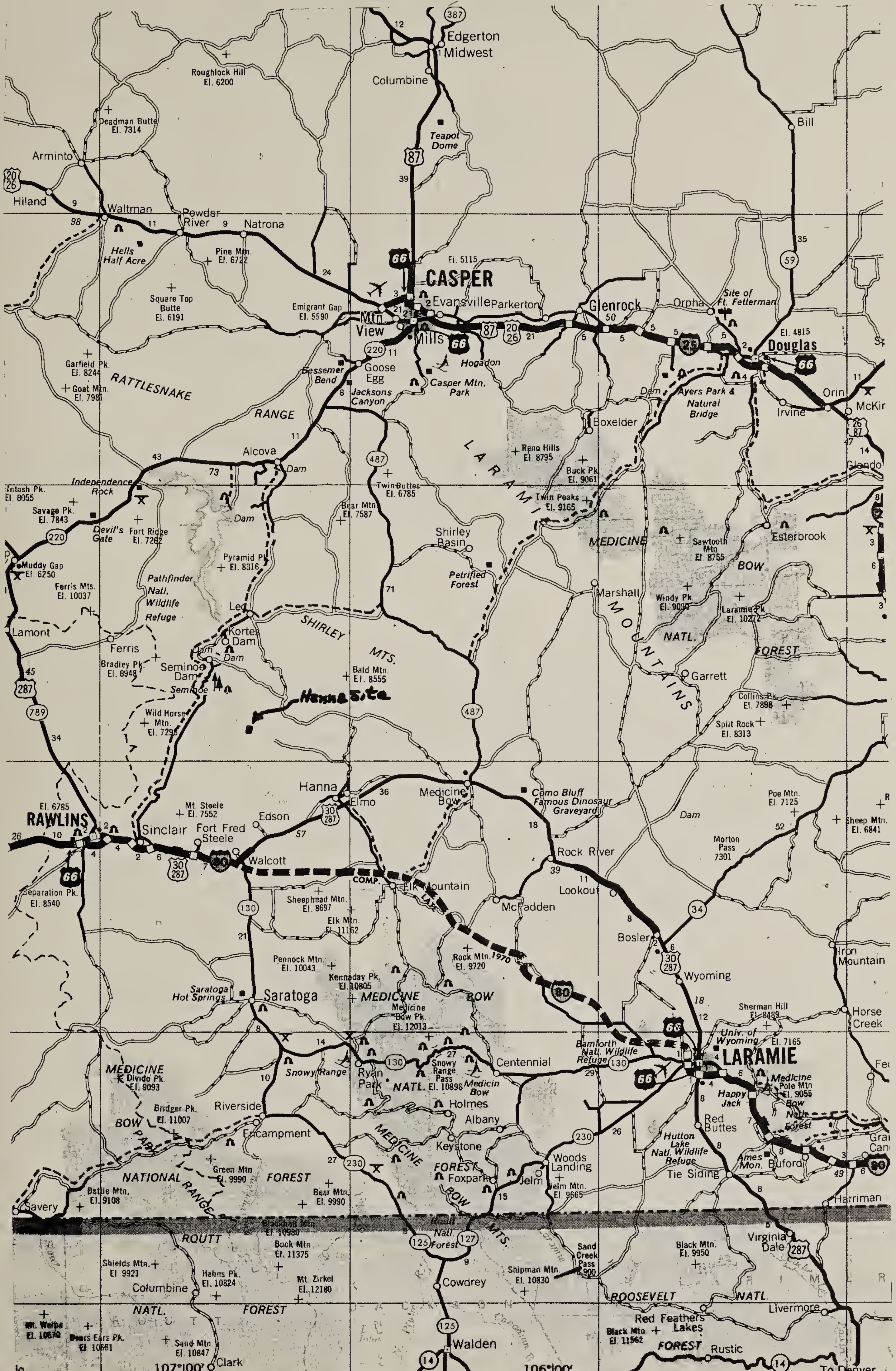
The vegetation on this site is primarily a Big Sagebrush Community comprised of shrubs, grasses, and grasslike plants, and forbs to be discussed in detail under the Vegetation section.

One plant, halogeton, which is an invader, plays an important part in plant succession following overgrazing or topsoil disturbance. Halogeton is usually the first plant to invade disturbed areas and effectively utilizes all of the available soil, moisture, and nutrients. It produces seed in large quantity and can crowd out or prevent other vegetation from becoming established. Halogeton is poisonous to sheep when eaten in large quantities. There is considerable evidence of large scale halogeton invasion on disturbed lands within the study area. To prevent invasion and establishment of halogeton on disturbed land, perennial vegetation must be established soon after disturbance.

There are a variety of aquatic and terrestrial animals which exist within the study area. Those discussed in this report include only the more prominent species based on numbers, economic importance and significance. Terrestrial animals include antelope, mule deer, cottontail rabbits, coyotes, badger, prairie dogs, jackrabbits, and ground squirrels. The most prominent terrestrial birds include sagegrouse, morning doves, golden eagles, bald eagles, marsh, red-tailed, and sparrow hawks, kildeer, horned lark, cliff swallow, magpie, sage thrasher, and brewers sparrow.

Aquatic animals of significance in the vicinity of the study site include waterfowl, beaver, and muskrat. The North Platte River, Seminoe Reservoir, and the Medicine Bow River presently support a variety of game and non-game species. Primary game fish species include rainbow trout, brown trout, and walleye pike. There are no perennial streams nor impoundments within the study area.

Plate 1. Hanna Basin Study Site



There are three wildlife species which may inhabit the study area and are listed as rare or endangered by the Wyoming Game and Fish Commission as follows:

1. Spotted bat
2. Prairie falcon
3. Burrowing owl

Water based recreation in the general area of the study site is primarily confined to boating, fishing, picnicking, and camping on the Seminoe Reservoir and the North Platte River. These bodies of water are within view of the study site. A recent socio-economic study in the Hanna Basin shows that hunting and fishing are the main recreation activities of both the old residents, newcomers, and recreation visitors to the area.

An independent survey by the Wyoming State Archeologist and his staff has been conducted in the study area. Nine archeological sites have been located. None were considered unique or critical but two were considered important enough to warrant further study prior to any mining disturbance.

Climate

The climate at Seminoe Dam is classified as semiarid. Mean monthly temperatures at the Seminoe Dam Weather Substation for the period 1938 through 1972 are presented in Figure 1. The mean annual temperature for the same period of record was 43.3° F. The extremes observed at Seminoe Dam are a maximum of 98° F. on July 20, 1964, and a minimum of -31° F. on January 19, 1963. Late spring and early fall freezes are not uncommon. At the Rawlins weather station (not far or dissimilar from the study area) the average last occurrence of 32° F. in the spring is May 31, and the average first occurrence of 32° F. in the fall is September 10.

Precipitation at the Seminoe Dam weather substations averaged 12.37 inches annually. The mean monthly precipitation amounts for the period 1938 through 1972 for January through December were 0.59, 0.79, 1.16, 1.63, 1.97, 1.57, 0.69, 0.67, 0.82, 1.07, 0.76, and 0.65 respectively.

Forty-two percent of the annual precipitation occurs in the spring months of April, May, and June. The greatest one month amount observed at Seminoe Dam was 5.98 inches in May 1965. The least amounts of precipitation observed in one month were 0 inches in August 1940, and a trace in September 1952. The greatest amount of precipitation measured in one day at Seminoe Dam was 3.70 inches on May 14, 1965. The following table presents the expected short duration maximum rainfall amounts for selected return periods

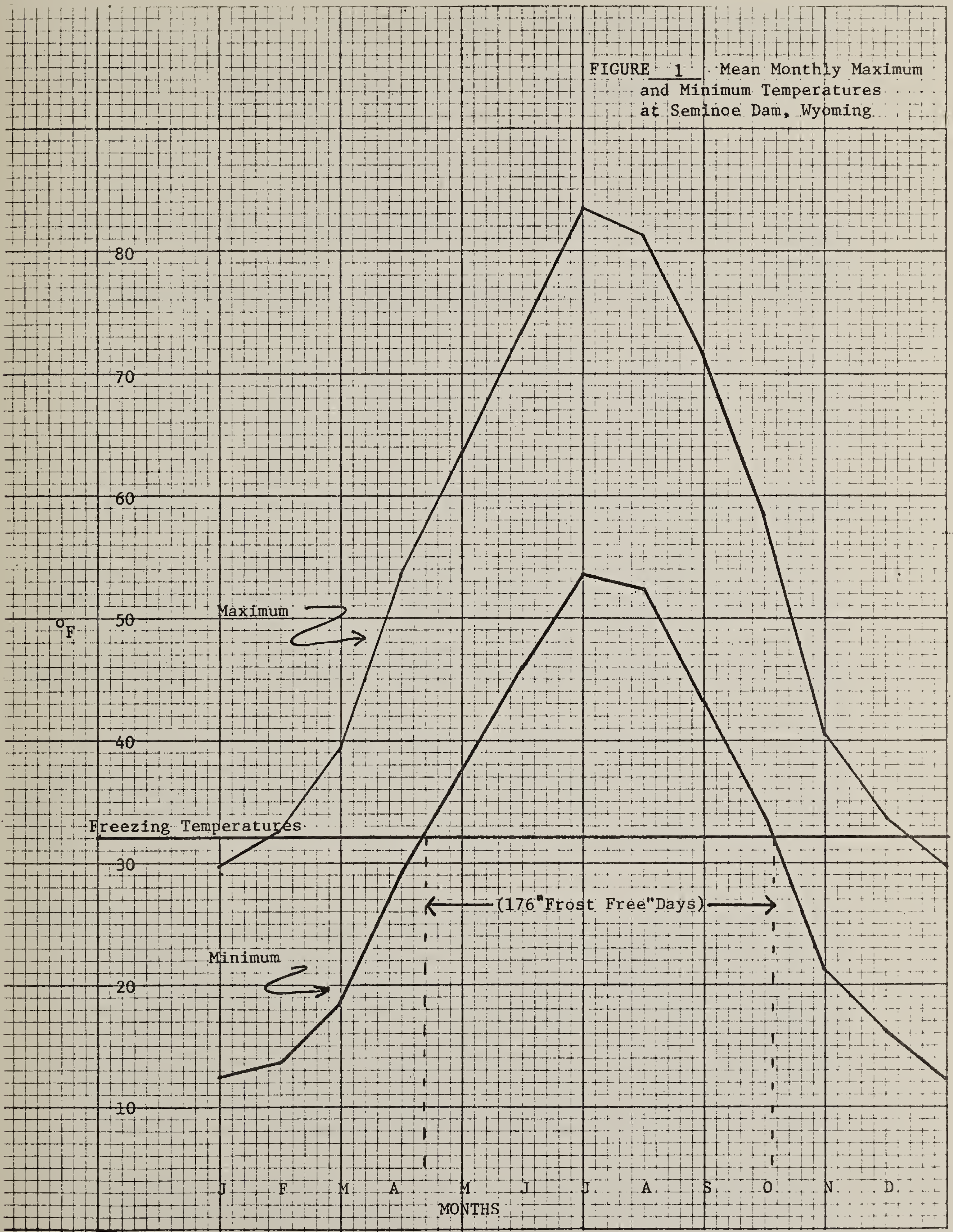


FIGURE 1 Mean Monthly Maximum and Minimum Temperatures at Seminoe Dam, Wyoming
80
70
60
50
°F
40
30
20
10
Maximum
Minimum
Freezing Temperatures
(176 "Frost Free" Days)
J F M A M J J A S O N D
MONTHS

and for various durations of precipitation:

Short Duration Maximum Rainfall Amounts
for Selected Return Periods
Seminoe Dam and Reservoir
(in inches and tenths)

Return Period (years)	Duration of Precipitation 30 min	1 hour	2 hours	3 hours	6 hours	12 hours	24 hours
1	0.4	0.5	0.6	0.7	0.8	0.9	1.1
2	0.5	0.6	0.8	0.9	1.0	1.3	1.4
5	0.7	0.9	1.2	1.3	1.4	1.7	1.9
10	0.9	1.1	1.3	1.5	1.7	2.0	2.1
25	1.1	1.3	1.7	1.8	2.0	2.4	2.7
50	1.2	1.5	1.8	2.0	2.4	2.7	3.2
100	1.4	1.8	2.1	2.2	2.6	3.1	3.5

Snow is the common form of precipitation from October through May, and blizzards, generally lasting from one to three days, occur every winter. One of the worst blizzards of record was in January 1949, when there were 1.10 inches of precipitation measured at Seminoe Dam, with 48 inches of snow measured on the ground at the observation point.

The area is subjected to high winds throughout much of the year--primarily due to the high elevation and rolling hills. The average annual wind speeds range from 12 to 14 miles per hour. Some winters, exceptionally high winds occur, such as the winds on January 11, 1972. The highest one-minute wind speed on that day at Casper was 51 miles per hour.

The growing season is approximately 60 - 70 days. This is estimated by the time between the date that mean monthly minimum temperatures exceed 32° F. and the date potential evapotranspiration (PET) is greater than available moisture. High summer temperatures, low humidity and low precipitation result in PET rates exceeding available moisture during July, August and September. Mean minimum temperatures generally exceed 32° F. in late April. The result is an average growing season beginning in late April and lasting until early July. There is also a 3 - 4 week period in late September to late October during which fall planting should be successful.

Based upon the above data it is apparent that the most important weather-related factor influencing techniques and procedures selected for site restoration are low annual precipitation rate and potential evapotranspiration of the area. The low average

yearly precipitation of 12.37 inches, coupled with the erratic distribution pattern common throughout the year, and in addition to the relatively high wind velocities (also prevalent throughout the year), results in a very drouthy environment for seed germination and plant growth.

Additionally, it should be pointed out that slopes having a southerly aspect tend to be more drouthy than those with a northerly aspect since they are exposed to prevailing summer winds and the heating of the sun during a large part of the growing season. As a consequence, evaportranspiration rates are higher on south slopes than on north slopes and the establishment of vegetation is usually much more difficult on the south slopes.

The basically arid climate of the area (along with relatively high wind velocities), coupled with rather extreme temperature variations, contributes to adverse conditions during winter months. Dry, open, cold, and windy winter weather poses a considerable threat of winterkill of plants particularly on recently established vegetation.

Wind erosion is an important factor in the strip mining operations now underway in the area as well as in potential site restoration planning. Provisions for control of dust must be made in both mining and restoration methods and procedures until such time as revegetation of disturbed materials is sufficiently advanced to prevent dust and erosion damage to the growing plants.

Taking into account the existing and anticipated climatic, soil, moisture, and erosion factors, it is apparent that species used in revegetation of the disturbed areas should include those plants which will develop a quick ground cover in combination with other slower germinating and slower growing plants that will furnish the ultimate desirable ground cover.

PHYSICAL PROFILE

Topography

The Hanna Basin, located in south central Wyoming, is an intermountain basin with dimensions of about 35 miles by 20 miles. Eardley (1951) states that: "The Hanna Basin is bounded on the west by the Rawlins uplift, the north by the Sweetgrass uplift,1/ the south by the Medicine Bow Range, but on the east, it merges with the northwest end of Laramie Basin." Individual mountain ranges within the Sweetwater uplift and close to the Hanna Basin go by the names Seminoe, Shirley, Freezeout, and Ferris Mountains.

1/ This is an apparent typographical error and should be the Sweetwater uplift. The Sweetgrass uplift is in Montana.

The area is drained by the North Platte River and its tributary, the Medicine Bow River. The later river is the approximate northern boundary of the Hanna Basin coal fields.

Physiographically, the Hanna Basin is a part of the Wyoming Basin which is defined as "Elevated plains in various stages of erosion; isolated low mountains." (Fenneman, 1931.) Except for the low ridges of Mesa Verde Formation sandstone surrounding the Hanna Basin, the topography greatly resembles that of the Great Plains.

Elevations in the Hanna Basin vary from 6,400 to 7,900 feet. By comparison, Elk Mountain, lying to the south in the Medicine Bow Mountains, rises to 11,162 feet. To the northwest in the Ferris Mountains, elevations go up to 10,037 feet. Seminoe Reservoir which backs up water on the North Platte and Medicine Bow Rivers has a maximum water surface elevation of 6,358 feet. The mining town of Hanna, Wyoming, has an elevation of 6,779 feet.

The study site occupies 2400 acres in essentially an upland position located in the triangle lying between the Platte River and Medicine Bow River areas of Seminoe Reservoir which lie to the west and to the north and east, respectively. Elevations range from approximately 6360 feet at the normal reservoir water surface to slightly over 6600 feet in the northern portion of Section 31. General topography varies from gently sloping to steeply sloping with the breaks into the draws tributary to the rivers being very steeply sloping and having many rough-broken eroded areas. In addition, there are two playa (enclosed drainage basin) lake areas within the study site which are level.

Slopes throughout the study area are, as mentioned above, highly variable, ranging from 0 to 1 percent on the dry lake beds to almost vertical in some of the gully and break areas. The majority of the area consists of a rolling or undulating type of topography with slopes averaging 6 to 10 percent. The general shape of the surface of the land is governed, in large part, by the nature of the underlying bedrock formation. Uplifted bedrock formations in the area tend to be in the form of ridges running in a general southwest to northeast direction. Prevailing winds have tended to remove materials from the north and west slopes and deposit them on the leeward south and east slopes of these ridges. The resultant gently to moderately sloping ridges average 10 to 20 feet in relief above the general elevation of the surrounding terrain.

The above-mentioned gently to moderately steeply sloping areas are dissected by many drainageways or gullies of varying slope and intensity of erosion. Where these drainageways are very steep and severely eroded, there has been very little in the way of re-establishment of vegetation or weathering processes which would result in smoothing of the terrain. Consequently, the highly eroded

drainageways and breaks from the upland to the old river channels are very rough and rocky, appearing almost as badlands.

The appended topography sheets give a detailed picture of the study site, but it must be borne in mind that the contour interval for these sheets is 20 feet and the more minor topographical irregularities are not discernible on them.

Geology

Regional geology

The Hanna Basin is a separate basin, separate from the Laramie Basin by an anticlinal structure on its southeastern flank.

The Hanna Basin itself is unique because of the extreme thickness of the sedimentary rocks. Thirty thousand to in excess of 35,000 feet of sediments, ranging in age from Carboniferous to late Tertiary, overlie the basement complex. Only four formations out of at least 17 formations are known to contain coal. The formations listed by Dobbin, Bowen, and Hoots (1929) are as follows:

Formation	Thickness (feet)
North Park (Miocene?)	0 to 400
Unconformity	
*Hanna (early Eocene)	7,000
Unconformity	
*Ferris (lower part is uppermost Cretaceous)	6,500
Medicine Bow (uppermost Cretaceous)	4,000 to 6,200
*Lewis Shale	3,300
*Mesa Verde	2,200 to 2,700
Steel Shale	4,000 to 5,000
Niobrara (upper Cretaceous)	700
Carlile Shale (upper Cretaceous)	400
Frontier	725
Mowry Shale	120
Thermopolis Shale	180
Cloverly (lower Cretaceous)	128
Morrison (upper (?) Jurassic)	350
Chugwater (Triassic)	1,300
Embar (?) (Permian)	150
Tensleep (Pennsylvanian)	250
Probably pre-Pennsylvanian beds	?

*Coal bearing

Site geology

Within the study area, only one formation was encountered in the surface and subsurface investigations. This was the Ferris Formation. This formation is about 6,500 feet thick and is divided into two parts: the lower unit is of uppermost Cretaceous age and is about 1,110 feet thick while the upper unit is of Paleocene age and about 5,400 feet thick and contains many thick beds of coal.

The Ferris Formation rests conformably in the underlying Medicine Bow Formation but an unconformity exists between it and the overlying Hanna Formation. Both upper and lower units are of continental origin and reflect a tremendous climatic change since the subtropical coal swamps existed 60 million years ago.

Drilling operations in the Hanna Basin sampled the upper 200 feet of the Ferris Formation and encountered shale, mudstone, siltstone, fine to coarse-grained sandstone, and coal. Both the shales and sandstones are highly lenticular and cannot be traced nor projected between drill holes with any degree of confidence. Only through the process known as saturation drilling can these beds be correlated with any accuracy. Some success was achieved though in correlating between surface outcrops of coal and coal encountered in the drilling. Included in the appendix is a geologic map of the general area of the study site, and geologic sections taken through the drill holes.

Rock types encountered in the study were of five types: sandstone, siltstone, shale, mudstone, and coal. Accessory minerals, such as gypsum, sulfur, iron oxide, calcite and carbonaceous material were also logged. Shown below is a table showing some statistical data regarding the rock types:

	Sandstone	Siltstone	Shale	Mudstone	Coal
Percent of Total	30	30	30	3	7
Average Thickness (feet)	9.3	8.8	8.8	8.0	2.9
Maximum Thickness (feet)	36.7	54.0	54.3	10.1	14.0
Minimum Thickness (feet)	.5	1.5	.5	5.0	.3

The above values are only approximate because of gradational contacts, poor core recovery, and "lumping" in the logging technique rather than "splitting."

Surficial soil (geologic classification) deposits at the eight drill sites averaged 4.8 feet deep with a maximum depth of 7.7 feet and minimum of 1.4 feet. Often included in the depth of soil was residual or highly weathered formation rock. It should be pointed out that formation rock crops out at a great number of places in the study area.

Technique, procedures, and standards used in geologic studies

Techniques and procedures used to gather geologic data were a combination effort between the U.S. Geologic Survey and Bureau of Reclamation with the Geologic Survey doing the surface mapping and the Bureau of Reclamation doing the drilling.

Drilling was performed with a Failing 1500 truck-mounted drill rig. Initially air was used as the drilling fluid since this was the established procedure with local contract drillers. It soon became apparent though the air was not compatible with the Nq wireline core barrel. A larger core barrel may have allowed the use of air.

Water from Seminoe Reservoir was then tried and was successful. Occasionally, when drill water losses become excessive, it was necessary to supplement the water with a drilling additive known as "Revert." Revert is a biodegradeable drilling mud, with characteristics similar to bentonite, but does not affect the permeability of the formation rock.

Upon completion of each drilling run, the core was removed from the barrel and placed in standard core boxes. The USGS had a geologist at the drill at all times who would take samples of coal core.

Periodically, the boxes of core would be moved by truck to Denver where the core was megascopically logged by geologists. Upon completion of logging, representative samples of the various rock types were then used for laboratory analysis and greenhouse studies.

The drill program was laid out on the premise that the overall study was one of the overburden, not the coal. Therefore, the holes were located to statistically sample the study area with the realization in mind that one or two holes may not encounter coal within an economically strippable depth. However, using this approach, it becomes apparent that stripping will not take place where there is no coal. Therefore, a rule-of-thumb criteria, furnished by the USGS was used to control the depth of holes. This is the 1:10 ratio concept which says that for every ten feet of overburden, there must be one foot of coal for an economical stripping operation with a maximum depth of 200 feet.

If a drill hole was located in an area where the possibilities of hitting a suitable thickness of coal was questionable then the hole would be terminated short of 200 feet, with the assurances of the Geological Survey that a coal seam would not be encountered that would fall into the 1:10 ratio. The sample thus obtained provided information as to the overall physical characteristics of the overburden within the study area.

Drill holes were also located near section corners for easy access and to avoid unnecessary surface disturbance.

Geologic logs

Following are the geologic logs of drill holes MS-9001 through MS-9008. These logs have been revised to include a comparison of the various rock types encountered in the drill holes with the suitability of using these rock types as a plant growing medium. Ratings of suitable, doubtful, and unsuitable are used and the basis for these ratings are discussed under Evaluation of Overburden Material as Plant Growing Media.

The approximate location of the above drill holes is shown on plate 2. This map also indicates the locations of the geologic cross sections.

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF

FEATURE EMRIA · PROJECT BLM-Hanna Basin · STATE Wyoming

HOLE NO. MS-9001 · LOCATION See below · COORDS. N. E. · GROUND ELEV. 6620± · DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 9-30-74 · FINISHED 10-3-74 · TOTAL DEPTH 201.8 · BEARING ———

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See below · LOGGED BY N.B. Bennett, III · LOG REVIEWED BY N.B. Bennett, III

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole drilled with truck mounted Failing 1500 drill rig.

NQ wireline 0-201.8
Drilled with water 0-201.8

Water Levels

Level	Date	Hole Depth
81.2	10-2	86.0
Dry	10-3	159.0

Gray color water return.
Driller estimates 5-30% water loss 0-201.8

Hole located 620' N 67° W of

30	29
31	32

in section 30, R 83 W, T 24 N

TYPE AND SIZE OF HOLE: Nq

CORE RECOVERY (%): 71, 67, 53, 83, 43, 70, 91, 100, 100, 100, 82, 94, 100, 100, 73, 93

DEPTH (FEET) FROM (P, Cs, or Cm): 100

ELEVATION (FEET)	DEPTH (FEET)
6612.3	7.7
6610.2	9.8
6598.5	21.5
6595.3	24.7
6563.4	56.6
6559.4	60.6
6555.5	64.5
6555.0	65.0
6553.1	66.9
6545.4	74.6
6527.0	93.0
6526.5	93.5

CLASSIFICATION AND PHYSICAL CONDITION

0-7.7 Superficial Soil Deposits

0 -7.7 Silt and mudstone. Highly weathered formation rock starting at 1.2', mixed with silt and clay. Sandstone cobble(?) 3.4-3.8. Gray, tan, black.

7.7-201.8 Ferris Formation

7.7-9.8 Sandstone. Highly weathered. Fine grained. Fe stained. Organic top .8'. Near vertical joint 8.8-9.8. Rusty.

9.8-21.5 Shale. Fissile to fragmented by desiccation. Silty. No HCl reaction. Molds easily where moist. Hardness 3-4. Light gray to black.

21.5-24.7 Sandstone. Fine grained. Slightly carbonaceous. No HCl reaction. 2" to 7" pieces. Hardness 6-7. Tan to rusty.

24.7-56.6 Siltstone and Shale. Both gradational and sharp contacts. Black, dark gray and tan.
Siltstone: Carbonaceous. Few coal pods. Jointed in places with Fe stains on joint surfaces. Hardness 6.
Shale: Fissile and/or desiccated. Moist. Carbonaceous. Coal or lignitic zones at 24.7, 36.6, 38.8-39.5, 43.8-44.1, 53.6-54.1. Hardness 3.

56.6-60.6 Sandstone. Carbonaceous layering. Jointed with Fe stains. 1/8" coal layer at 59.1. Hardness 6-7.

60.6-64.5 Siltstone. Faint carbonaceous banding. No HCl reaction except 62.6-63.1 where it is highly calcareous. Jointed 61-62 with Fe stains. Hardness 7. Gray.

64.5-65 Coal. Very hard. Impure.

65-66.9 Siltstone. Same as 60.6-64.5. Jointed and broken.

66.9-74.6 Sandstone. Fine to coarse at bottom. Carbonaceous banding. Slight jointing. Hardness 7. Gray.

74.6-93 Siltstone. Grades into shale in places. Coal 75.7-76.3. Shale is fissile to fragmented and partially desiccated. Siltstone has slight carbonaceous banding. Few joints. No HCl reaction. Fragments to 1' pieces. Hardness 6.

93-93.5 Coal. Sample taken.

EXPLANATION

CORE LOSS · CORE RECOVERY

Type of hole . . . D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx – 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE EMRIA · PROJECT BLM-Hanna Basin · STATE Wyoming · SHEET 1 OF · HOLE NO. MS-9001

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF

FEATURE EMRIA PROJECT BLM-Hanna Basin STATE Wyoming

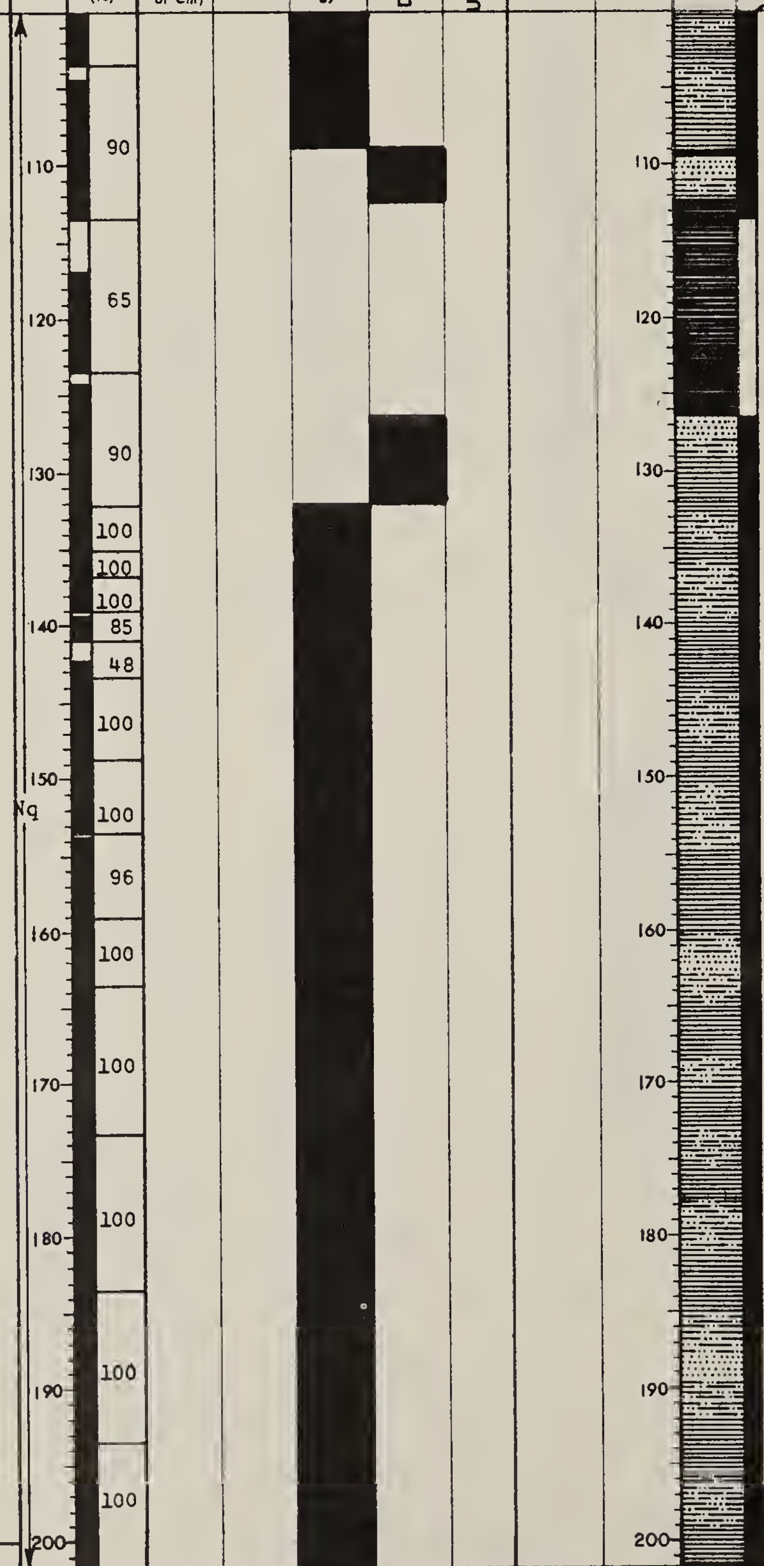
HOLE NO. MS-9001 LOCATION See below GROUND ELEV. 6620± DIP (ANGLE FROM HORIZ.) Vertical

COORDS. N. E.

BEGUN 9-30-74 FINISHED 10-3-74 TOTAL DEPTH 201.8 BEARING ———

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See below LOGGED BY N.B.Bennett, III LOG REVIEWED BY N.B. Bennett,III

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET) FROM (P, Cs, or Cm)	TO	SUITABILITY OF OVERBURDEN: SUITABLE	DOUBTFUL	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION



93.5-201.8 Shale and Siltstone. Mainly gradational. Few sandstone layers not exceeding 2.5' thickness. Coaly or lignitic zones 93.5-95.5, 109.1-109.4, 112.4-126.4 (poor). Few slickensides on coal.

Shale: Fissile to fragmented and desiccated. Moist in places. Hardness 3. Gray to black.

Siltstone: Carbonaceous banding. Few thin (-1/4") coal seams. Scattered joints with Fe stains. 2.5' maximum thickness. Gray with white and dark gray banding.

Total depth 201.8

CORE LOSS

CORE RECOVERY

Type of hole . . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . . P = Pocker, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series). . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE EMRIA PROJECT BLM-Hanna Basin STATE Wyoming SHEET 2 OF HOLE NO. MS-9001

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE EMRIA PROJECT BLM - Hanna Basin STATE Wyoming

HOLE NO. MS-9002 LOCATION See below COORDS. N. -- E. -- GROUND ELEV. 6480± DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 10-4-74 FINISHED 10-9-74 TOTAL DEPTH 200.8 BEARING --

DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED See below LOGGED BY N. B. Bennett, III LOG REVIEWED BY N. B. Bennett, III

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET) FROM (P, Cs, or Cm)	TO	SUITABILITY OF OVERBURDEN: SUITABLE	DOUBTFUL	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION

Notes on water losses and levels, casing, cementing, caving, and other drilling conditions:

Drilled with Failing 1500 truck mounted rig.

Push samples 0-1.4.

NQ wireline with D-core 1.4-200.8.

10-15% water loss 1.4-103.5.

Full water loss 103.5-143.5.

10-20% loss 143.5-200.8.

Hole located 140 ft. S 20° W from

29	28
32	33

in Sect. 32, R 83 W, T 24 N.

Hole formerly numbered MS-9005.

Water Levels

Date	Level	Hole Depth
10-8-74	48.7	72.5
10-9-74	37.9	138.7

Type and size of hole: Nq

Core recovery (%): 100, 67, 57, 6, 63, 0, 45, 80, 100, 97, 100, 100, 77, 98, 100, 100, 100

Elevation (feet)	Depth (feet)
6478.6	1.4
6474.1	5.9
6449.6	30.4
6447.5	32.5
6436.1	43.9
6434.6	45.4
6432.6	47.4
6431.6	48.4
6418.3	61.7
6412.4	67.6
6410.7	69.3
6404.5	75.5
6390.9	89.1

Classification and physical condition:

Superficial Soil Deposits

0-1.4 - Silt: Highly calcareous. Organic material at top. Tannish-brown.

Ferris Formation

1.4-5.9 - Siltstone: Slightly calcareous. 1/4" fragments to 1/2" thick discs. Poor recovery. Tan and rusty.

5.9-30.4 - Shale: Silty. Gypsum crystals 22.9. Siltstone 25.2-26.7. Fe stained areas but especially 23.5-25.5. Slickensides on joint with Fe stains at 25.1; other scattered joints. Fragmented by desiccation to fissile. Gray, brownish black.

30.4-32.5 - Siltstone: Sandy. Sand increases with depth. Few carbonaceous bands. No HCl reaction. Breaks along 20° dipping bedding planes. Gray with rusty stains.

32.5-43.9 - Sandstone: Silty. Quartzose. Siltstone pod at 34.9. Fe stained 85° dipping joint at 43.8. Fine-grained at top to coarse at bottom. White, tan.

43.9-45.4 - Shale: With thin coal stringers. Carbonaceous to 44.9. Thin bedded to fragmented. Black, gray.

45.4-47.4 - Siltstone: Silty, carbonaceous. Hardness 6-7. Gray.

47.4-48.4 - Shale: With coal stringers. Thin bedded. Black, dark gray.

48.4-61.7 - Siltstone: Fine sandy with increasing sand toward bottom. Few shaley zones. Few joints. Thick bedded. Hardness 6. Gray to light gray at bottom.

61.7-67.6 - Sandstone: Silty. Scattered carbonaceous and coal stringers. Fine coarse 63-65.5. Massive. Light gray to tan.

67.6-69.3 - Siltstone: Thin bedded. Joint at 68.6. Gray.

69.3-75.5 - Coal: With carbonaceous shale. Thin bedded. Sample apparently taken near 75.5. Black.

75.5-89.1 - Shale: Carbonaceous and coaly zones. More coal and carbonaceous material 87.9-88.4. No HCl reaction. Thin bedded to desiccated. Several joints. Slickensided at 89.0. Gray to dark gray.

89.1-104.7 - Siltstone: Zones of carbonaceous banding. Slightly calcareous. Massive. Hardness 7. Several well developed clean joints dipping 60°. Gray with darker bandings.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole .... D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE EMRIA PROJECT BLM-Hanna Basin STATE Wyoming SHEET 1 OF 2 HOLE NO. MS-9002

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

FEATURE EMRIA PROJECT BLM - Hanna Basin STATE Wyoming

HOLE NO. MS-9002 LOCATION See below COORDS. N. -- E. -- GROUND ELEV. 6480± DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 10-4-74 FINISHED 10-9-74 TOTAL DEPTH 200.8 BEARING --

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See below LOGGED BY N. B. Bennett, III LOG REVIEWED BY N. B. Bennett, III

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET) FROM (P, Cs, or Cm)	TO	SUITABILITY OF OVERBURDEN: SUITABLE	DOUBTFUL	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
	Nq	67						6375.3	104.7			104.7-107.2 - Coal and carbonaceous shale. Stringers of better grade coal. Thin bedded. Black and dark gray.
		76						6372.8	107.2			107.2-121.1 - Shale: Scattered coal flakes and thin seams. Slickensided at 113.6. Thin bedded to desiccated. Hardness 6. Core missing 108.9-111.7. Gray.
		100						6358.9	121.1			121.1-136.1 - Sandstone and siltstone: Highly intermixed. Coaly 128.5-128.9. Generally massive. Highly slickensided with glossy Fe stains 134.4-134.8 but core in good condition here. Hardness 7. Few joints. Fragments 128.5-129.5. Gray with scattered black carbonaceous bandings.
		82						6343.9	136.1			136.1-148.4 - Siltstone: With shaley carbonaceous zones. Thin bedded to massive. Joint at 146.2. Hardness 6-7. Gray to black.
		100						6331.6	148.4			148.4-150.5 - Sandstone: Silty. Quartzose. Slightly calcareous. Coarse grained. Friable. Massive - one piece. White.
		100						6329.5	150.5			150.5-154.9 - Shale: No HCl reaction. Thin bedded to fissile. Hardness 5-6. Gray to dark gray.
		92						6325.1	154.9			154.9-167.3 - Siltstone: Moderately calcareous. Generally massive. Good condition. Hardness 7. Gray with darker carbonaceous banding.
		100						6312.7	167.3			167.3-169.5 - Shale: Carbonaceous with thin coal. No HCl reaction. Thin bedded. Hardness 6. Dark gray, black.
		100						6310.5	169.5			169.5-186.5 - Siltstone: Varying fine sand content. Shaley zones. More carbonaceous banding at top. Massive. Joint at 184.2. Grades into next unit. Gray to tan.
		92						6293.5	186.5			186.5-200.8 - Shale: No HCl reaction. Sandstone and siltstone 193.5-195.5. Thin bedded. Hardness 6-7. Gray to very dark gray at bottom.
		94						6279.2	200.8			T.D. 200.8
		100										
		95										
		100										

EXPLANATION

CORE LOSS

CORE RECOVERY

Type of hole . . . D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE EMRIA PROJECT BLM-Hanna Basin STATE Wyoming SHEET 2 OF 2 HOLE NO. MS-9002

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF ......

FEATURE: EMRIA | PROJECT: BLM - Hanna Basin | STATE: Wyoming

HOLE NO.: MS-9003 | LOCATION: See below | GROUND ELEV.: 6435± | DIP (ANGLE FROM HORIZ.): Vertical

COORDS. N. .... E. .... | TOTAL DEPTH: 150.4 | BEARING: ——

BEGUN: 9-23-74 | FINISHED: 9-28-74

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: See below | LOGGED BY: N.B. Bennett, III | LOG REVIEWED BY: N.B. Bennett, III

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET) FROM (P, Cs, or Cm)	TO	SUITABILITY OF OVERBURDEN: SUITABLE	DOUBTFUL	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION

Notes:

Drilled with Failing 1500 truck-mounted drill rig.

Drilled dry 0-3.9. Water 3.9-150.4.

100% water loss 3.9-150.4.

Had trouble with hole caving above 12.0'.

Nx core 0-10.3. Nq wireline 10.3-150.4.

Water Levels

Date	Level	Hole Depth
9-28	86.9	113.5
9-30	78.1	150.4

This hole was formerly numbered MS-9008.

Hole located 300' S.45° E of

36	31
1	6

in Section 6, R 83 W, T 23 N.

Type and size of hole: Nx (0-10.3); Nq (10.3 onward)

Core recovery (%): 100, 46, 62, 30, 0, 92, 78, 71, 83, 98, 100, 100, 100, 97, 100, 100

Elevation / Depth:

Elevation	Depth
6431.1	3.9
6430.4	4.6
6400.2	34.8
6392.6	42.4
6385.8	49.2
6372.4	62.6
6362.6	72.4
6346.1	88.9
6336.8	98.2

Classification and Physical Condition:

0-3.9 Superficial Soil Deposits

0-3.9 Silt and residual sandstone at bottom of interval. Coarse-grained sandstone. Little to highly calcareous.

3.9-150.4 Ferris Formation

3.9-4.6 Sandstone-fine to medium-grained. Slightly friable. Quartzose. Highly calcareous. Whitish. Hardness 6.

4.6-34.8 Shale-silty, grades in and out of siltstone. Gray. Moderately to highly calcareous 4.6-22.6, slightly calcareous below 22.8. Highly Fe stained 24.2 and 30.5. Black clayey shale 22.6-22.8. 1/2" fragments 10.5-12.7, other pieces 4" to 1/4" disc-shaped. Very slow breakdown in water. One near vertical joint. Hardness 4-5.

34.8-42.4 Sandstone- fine to medium grained. Ferruginous. Increasing carbonaceous content below 37.6. Rusty color to 37.6, tan 37.6-42.4. No HCl reaction. Slightly friable to none. 30° dipping joint 37.8-38.8; broken along here with gypsum deposited on joint plane. Hardness 6.

42.4-49.2 Shale-silty. 30° dipping bedding plane at 49.2. Slow breakdown in water. Partially desiccated. Black to gray. Hardness 3-4.

49.2-62.6 Sandstone-fine to coarse-grained. Slightly calcareous to ferruginous. Some carbonaceous silty layers. Vug at 59' in joint surface. 1.5' maximum length. Rusty to whitish. Hardness 6.

62.6-72.4 Shale-clayey to silty. Fissile. Partially desiccated in places. No to slow breakdown in water. Hardness 3-4. Gray to black.

72.4-88.9 Sandstone-fine-grained. Silty to shaley zones. Carbonaceous. No HCl reaction. 5°-10° dipping, carbonaceous planes. 1.8' maximum length. Hardness 5-6. Dark to light gray.

88.9-98.2 Shale and Siltstone-fissile shale to massive siltstone. Shale partially desiccated. Some sandy zones. Carbonaceous pods in siltstone. No HCl reaction. Hardness 5-6 in siltstone, 4-5 in shale. Gray to dark gray.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole .... D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing

	Ex	Ax	Bx	Nx
Approx. size of hole (X-series)	1-1/2"	1-7/8"	2-3/8"	3"
Approx. size of core (X-series)	7/8"	1-1/8"	1-5/8"	2-1/8"
Outside dia. of casing (X-series)	1-13/16"	2-1/4"	2-7/8"	3-1/2"
Inside dia. of casing (X-series)	1-1/2"	1-29/32"	2-3/8"	3"

FEATURE: EMRIA | PROJECT: BLM-Hanna Basin | STATE: Wyoming | SHEET 1 OF .... | HOLE NO. MS-9003

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF ....

FEATURE EMRIA PROJECT BLM-Hanna Basin STATE Wyoming

HOLE NO. MS-9003 LOCATION See below COORDS. N. ... E. ... GROUND ELEV. 6435± DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 9-23-74 FINISHED 9-28-74 TOTAL DEPTH 150.4 BEARING ----

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See below LOGGED BY N.B. Bennett, III LOG REVIEWED BY N.B. Bennett, III

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET) FROM (P, Cs, or Cm)	DEPTH (FEET) TO	SUITABILITY OF OVERBURDEN: SUITABLE	DOUBTFUL	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
	Nq	100 100 90 86						6332.4	102.6			98.2-102.6 Sandstone-fine to 101.6, coarse 101.8-102.6, shale separates these two zones. Highly calcareous 101.1-101.6. Siltstone 99.3-99.7. Poorly cemented at bottom. Hardness 6-7. Gray to whitish. 102.6-150.4 Siltstone and shale-alternating with thin (1.3' maximum) medium to coarse-grained sandstone layers. Most contacts sharp rather than gradational. Shale: Thinly bedded to fissile. Partially desiccated. Molds and breaks easily with fingers. Slightly coaly 142.7-143.7; other zones silty to clayey, hardness 3. Black to dark gray. Siltstone: Carbonaceous. No HCl reaction. No breakdown in water. Maximum thickness 1.1'. Hardness 6. Scattered joints. Light to dark gray.
								6284.6	150.4			Total Depth 150.4

EXPLANATION

CORE LOSS

CORE RECOVERY

Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series). . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE EMRIA PROJECT BLM-Hanna Basin STATE Wyoming SHEET 2 OF .... HOLE NO. MS-9003

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE EMRIA PROJECT BLM-Hanna Basin STATE Wyoming

HOLE NO. MS-9004 LOCATION See below COORDS. N. ______ E. ______ GROUND ELEV. 6490± DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 9/10/74 FINISHED 9/21/74 TOTAL DEPTH 201.4 BEARING ———

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See below LOGGED BY N.B. Bennett, III LOG REVIEWED BY N.B. Bennett, III

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET) FROM (P, Cs, or Cm)	TO	ELEVATION (FEET)	DEPTH (FEET)	CLASSIFICATION AND PHYSICAL CONDITION
Drilled with Failing 1500 truck mounted drill rig. Drilled dry 0-3.3. Drilled with water 3.3-22.9, 40.8-50.4, 55.6-71.5. Drilled with Revert 22.9-40.8, 50.4-55.6, 71.5-201.4. Hole located 160 ft. N 45° W of 6 | 5 / 7 | 8 in Sect. 6, R 83 W, T 23 N. Hole originally numbered MS-9009.	Nq	90, 50, 60, 10, 83, 79, 100, 83, 99, 96, 85, 100, 100, 78, 100, 97, 100, 100, 100, 98, 100, 100	100		6483.0 6470.8 6468.4 6465.7 6463.5 6459.5 6452.3 6448.0 6447.2 6441.1 6401.7	7.0 19.2 21.6 24.3 26.5 30.5 37.7 42.0 42.8 48.9 88.3	see below

Suitability of overburden: 0–1 Suitable; 1–10 Doubtful; 10–42.8 Suitable; 42.8–50 (unmarked); 50–59.5 Doubtful; 59.5–100 Unsuitable.

Water Levels

Date	Level	Hole Depth
9-11	30.9	40.8
9-17	30.9	50.4
9-18	18.8	71.5
9-19	22.3	103.5
9-20	50.0	153.5

CLASSIFICATION AND PHYSICAL CONDITION

Surficial Soil Deposits

0 - 7.0 Silt & Clay. Sandy. Mostly plastic. No HCl reaction. Scattered Fe stains. Some organic matter. Brown and black.

Ferris Formation

7.0- 19.2 Siltstone. Fine sandy. Moderately calcareous 16.7-19.2. No HCl reaction below this. Weathered and broken, 5" maximum length. Few joints with weathered surfaces. Very slow breakdown in water. Hardness 5-6. Light gray to tannish gray.

19.2- 21.6 Shale. Silty. Crushed to 20.2. Thin bedded. Gray.

21.6- 24.3 Siltstone. 1" to 2" pieces. Hardness 5. Tan to gray.

24.3- 26.5 Sandstone. Fine grained. Highly calcareous. 30° dipping joint at 25.3. Tan.

26.5- 30.5 Siltstone. Slightly calcareous. Slightly carbonaceous near bottom. Fe stained and weathered at 30'. Tan and gray.

30.5- 37.7 Sandstone. Fine to very fine grained at bottom. Increasing carbonaceous banding. Calcareous. Nonfriable. Up to 2.8' long pieces. Tan to slightly rusty color.

37.7- 42.0 Siltstone. No HCl reaction. Tan and gray.

42.0- 42.8 Shale. Thin bedded to fissile. Desiccated. Gray.

42.8- 48.9 Coal and highly carbonaceous shale.

48.9- 88.3 Shale. Thin bedded to fissile. Desiccated in parts. Fine sandy zones. Increasing sandstone and siltstone with depth. Few joints. Moist. No HCl reaction. Slow to moderate breakdown in water. Hardness 3-4. Gray. Black.

88.3-104.2 Sandstone. Fine, coarse at bottom. Few-3" carbonaceous layers. Calcareous to 94.7, then no HCl reaction. Very friable and silty below 94.7. Light gray.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole . . . . D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx – 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE EMRIA PROJECT BLM-Hanna Basin STATE Wyoming SHEET 1 OF 2 HOLE NO. MS-9004

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

FEATURE: EMRIA — PROJECT: BLM-Hanna Basin — STATE: Wyoming

HOLE NO.: MS-9004 — LOCATION: See below — GROUND ELEV.: 6490± — DIP (ANGLE FROM HORIZ.): Vertical

COORDS. N. ...... E. ......

BEGUN: 9/10/74 — FINISHED: 9/21/74 — TOTAL DEPTH: 201.4 — BEARING: ——

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: See below — LOGGED BY: N.B. Bennett, III — LOG REVIEWED BY: N.B. Bennett, III

Column headings: NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | SUITABILITY OF OVERBURDEN: DEPTH (FEET) FROM (P, Cs, or Cm) / TO; SUITABLE; DOUBTFUL; UNSUITABLE | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION

Type and size of hole: Nq

Core recovery (%), top to bottom: 94, 100, 84, 68, 100, 100, 100, 91, 91, 100, 100, 99, 95, 91, 100, 100, 93, 100, 86

Depth scale: 110, 120, 130, 140, 150, 160, 170, 180, 190, 200

Depth to: 201.4

Suitability of overburden: unsuitable 104.2–114.1; doubtful 114.1–172.8; unsuitable 172.8–201.4

Elevation (feet)	Depth (feet)
6385.8	104.2
6378.9	111.1
6377.7	112.3
6375.9	114.1
6367.2	122.8
6360.3	129.7
6317.2	172.8
6303.3	186.7
6295.2	194.8
6288.6	201.4

Classification and Physical Condition

104.2-111.1 Siltstone. Shaley layers. Becomes carbonaceous and black toward bottom. Light gray.

111.1-112.3 Coal. Highly carbonaceous shale. Thin bedded. Black.

112.3-114.1 Siltstone. Carbonaceous. Thin coal seam. Sandstone 113-113.5 calcareous. Gray.

114.1-122.8 Coal. Laminated. Carbonaceous shale 119.8-120.3. Sample taken 115.5-117.4. Black.

122.8-129.7 Siltstone. Fine sandy. Scattered carbonaceous banding. No HCl reaction. Up to 2' long pieces. Hardness 6. Gray.

129.7-172.8 Sandstone. Fine to coarse grained. Interbedded siltstone and shale. Low grade coal 162.4-162.7. Carbonaceous banding and pods. Up to 3.4' long pieces. Light gray, gray, black.

Siltstone not over 1.5' thick.
Shale is desiccated with .4' maximum thickness.
Coal 148.1-151.5.

172.8-186.7 Shale. Silty. Highly carbonaceous to coaly 180-181.6. Very slow breakdown in water. Hardness 5-6, Gray, black.

186.7-194.8 Siltstone. Carbonaceous banding. Sandy layers to sandstone, gradational between the two. No HCl reaction. Hardness 6-7. Gray.

194.8-201.4 Shale & Coal. Thin bedded. Most of core missing. Black to dark gray.

CORE LOSS
CORE RECOVERY

Type of hole . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: EMRIA — PROJECT: BLM-Hanna Basin — STATE: Wyoming — SHEET 2 OF 2 — HOLE NO.: MS-9004

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE: EMRIA — PROJECT: BLM - Hanna Basin — STATE: Wyoming

HOLE NO.: MS-9005 — LOCATION: See below — GROUND ELEV.: 6425± — DIP (ANGLE FROM HORIZ.): Vertical

COORDS. N.: -- E.: --

BEGUN: 8-21-74 — FINISHED: 8-30-74 — TOTAL DEPTH: 200.0 ft. — BEARING: --

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: See below — LOGGED BY: N. B. Bennett, III — LOG REVIEWED BY: N. B. Bennett, III

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET) FROM (P, Cs, or Cm)	DEPTH (FEET) TO	SUITABILITY OF OVERBURDEN: SUITABLE	DOUBTFUL	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION

Notes on drilling conditions:

Drilled with Failing 1500 Truck-mounted drill rig.

Drive sample 0-1.2. Air drilled 1.2-40.8. Water drilled 40.8-200.

NQ wireline with D core 1.2-200.

Plastic pipe installed in hole 0-133.5.

Water Levels

Date	Level	Hole Depth
8-26	Dry	32.7
8-27	40.8	40.8
8-28	41.5	53.5
8-29	17.5	122.6
8-30	36.8	196.8

This hole was originally numbered MS-9011.

Hole located in approximate center of Section 12, R. 84 W., T. 23 N.

Core recovery (%): 100, 0, 36, 70, 46, 50, 34, 22, 75, 100, 26, 56, 100, 100, 95, 92, 100, 100

Elevation / Depth (feet):

Elevation	Depth
6421.5	3.5
6416.0	9.0
6406.0	19.0
6375.3	49.7
6374.5	50.5
6366.8	58.2
6359.7	65.3
6353.5	71.5
6348.6	76.4
6332.6	92.4
6326.8	98.2

Classification and physical condition:

Surficial Soil Deposits

0-3.5' SILT: Sandy. Vegetative matter top 1'. Tan.

Ferris Formation

3.5-9.0 SHALE: Fissile to 1/4" fragments. Scattered Fe stains. No HCl reaction. Carbonaceous below 8.0'. Brownish gray. Weathered.

9.0-19.0 SILTSTONE: Blocky, 1/2" to 2" pieces. Scattered Fe stains. Rapid breakdown in water. No HCl reaction. Hardness 5-6. Tan. Weathered.

19.0-49.7 SHALE: Fissile to blocky. Scattered carbonaceous and coal pods. Minute gypsum seam at 23'±. Does not break down in water. Grades into underlying coal. Brown to black.
SANDSTONE: 41-43.5 (poor recovery)
SILTSTONE: 24-26 (poor recovery), 1" pieces, Fe stains.
COAL: 39.0-41.2

49.7-50.5 COAL: Lignite. Hardness 5. Breaks into 1/4" fragments.

50.5-58.2 SHALE: Grades from above coal. Slight breakdown in water. 1/2" to 2" flat pieces. Scattered carbonaceous material. No HCl reaction. Gray to black. SANDSTONE: 51.5-52.2, 2-45° dipping joints. Gray.

58.2-65.3 SANDSTONE: Very fine-grained. Slightly calcareous, silty. Fine horizontal dark carbonaceous banding. 2" to 1.4' pieces. Breaks irregularly with hammer blow. Breaks easier after short water submergence. Hardness 6. Gray.

65.3-71.5 SILTSTONE: Starts grading into shale and coal at 70.5. Scattered slickensides. No HCl reaction. Very slow to no breakdown in water. Hardness 5. Gray to black.

71.5-76.4 COAL: With minor carbonaceous and coaly shale and siltstone. Scattered slicks. 1" to 4" pieces. Hardness 4. Grades into underlying unit. Gray to black.

76.4-92.4 SANDSTONE: Silty. Very fine grained. Scattered thin carbonaceous bands. No HCl reaction except 88.2-

EXPLANATION

CORE LOSS

CORE RECOVERY

Type of hole . . . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

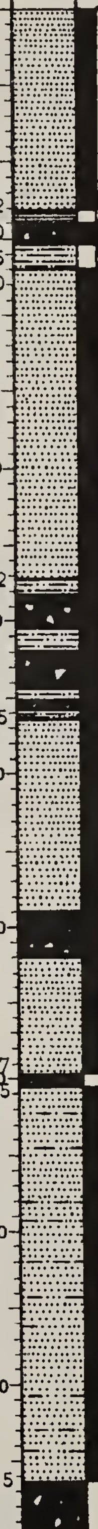
FEATURE: EMRIA PROJECT: BLM - Hanna Basin STATE: Wyoming

HOLE NO. MS-9005 LOCATION: See below COORDS. N. -- E. -- GROUND ELEV. 6425± DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 8-21-74 FINISHED: 8-30-74 TOTAL DEPTH: 200.0 ft. BEARING: --

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: See below LOGGED BY: N. B. Bennett, III LOG REVIEWED BY: N. B. Bennett, III

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET) FROM (P, Cs, or Cm)	TO	SUITABILITY OF OVERBURDEN: SUITABLE	DOUBTFUL	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
		100						6311.8	113.2			
		93						6311.0	114.0			
		96						6309.5	115.5			
		100						6308.0	117.0			
		89						6287.8	137.2			
		100						6278.5	146.5			
		99						6255.3	169.7			
		94						6254.5	170.5			
		94						6228.5	196.5			
		100						6225.0	200			
		100										
		100										
		100										
		100										
		100										



88.8 where it is highly calcareous. Grades into siltstone at various places. Hardness 7. Gray.

92.4-98.2 COAL: Breaks into 1" chunks or along 1/4" thick bedding. Sample taken by U.S.G.S. 95.8-97.0.

98.2-113.2 SANDSTONE: Very fine-grained. Silty. No HCl reaction. Becomes carbonaceous toward bottom. 1" to 3' long pieces. Does not breakdown in water. Gray. Good rock.

113.2-114.0 SHALE: Coaly and carbonaceous. Silty. Thin bedded. Does not disaggregate in water.

114.0-115.5 COAL: Interval taken by U.S.G.S. - no log.

115.5-117.0 SILTSTONE: 1" thick bedding. Hardness 6. No disaggregation in water. Gray.

117.0-137.2 SANDSTONE: Fine grained. Mostly silty but few calcareous zones. Slightly friable. Black carbonaceous banding scattered throughout but increasing toward bottom. Hardness 6-7. Few cores in excess of 3' long. Very light gray to white with black flecks.

137.2-146.5 COAL, MUDSTONE, AND SILTSTONE: Mostly coal. Gradational. Low grade coal is 2.5' thick. Siltstone at bottom has thin carbonaceous seams.

146.5-169.7 SANDSTONE: Fine-grained. Same as 117.0-137.2. One long near vertical joint 150.7-152.7. COAL: 159.0-162.1.

169.7-170.5 COAL: Grades into black shale at bottom. 1/2" thick bedding in shale to blocky in coal.

170.5-196.5 SANDSTONE: Very fine to fine grained. Silty except 187.5-190.5 where it is highly calcareous. Fragments to 4' pieces. Some siltstone. Scattered carbonaceous banding. Hardness 6-7. Light gray to white.

196.5-200.0 COAL: Metallic-yellow flecks in coal. Grades into carbonaceous siltstone and shale at 198.5. 1/4" to 6" thick beds in siltstone.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE: EMRIA — PROJECT: BLM - Hanna Basin — STATE: Wyoming

HOLE NO. MS-9006 — LOCATION: See below — COORDS. N. -- E. -- — GROUND ELEV. 6500+ — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 8-6-74 — FINISHED: 8-19-74 — TOTAL DEPTH: 100.0 — BEARING: --

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: See below — LOGGED BY: Johnson-Bennett — LOG REVIEWED BY: N. B. Bennett, III

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET) FROM (P, Cs, or Cm)	TO	ELEVATION (FEET)	DEPTH (FEET)
Drilled with Failing 1500 truck mounted drill rig.	4" cs	100				
Drive sample 0-3.1		0			6493.4	6.6
Air drilled 3.1-52.2		56			6489	11.0
Water drilled 52.2-62.5		57				
Air drilled 62.5-87.5		26				
Water drilled 87.5-100		47			6471	29.0
Used 750 gal. water to drill 52.2-62.5; 1,000 gal. 87.5-94.1 and 94.1-100.		100			6455.6	44.4
Used NQ wireline 0-100.		100			6453.4	46.6
		100			6450	50.0
	NQ wl	82			6449	51.0
		?			6447.8	52.2
		31			6446.5	53.5
		50			6441.7	58.3
		100			6401.4	98.6
		100				
		100				
		59				
		100				

Water Levels

Date	Level
8-17-74	68.8
8-19-74	67.9

Hole located 105' N60W of 32 | 33 / 5 | 4 in Section 32, R 83 W, T 24 N.

SUITABILITY OF OVERBURDEN: SUITABLE / DOUBTFUL / UNSUITABLE — GRAPHIC LOG — SAMPLES FOR TESTING

CLASSIFICATION AND PHYSICAL CONDITION

0-6.6 Superficial Soil Deposits

0-6.6 SILT: Slightly sandy, tan.

Ferris Formation

6.6-11.0 SANDSTONE AND SILTSTONE: Light gray to light brownish gray. Slight to moderately clayey. Non-calcareous with much woody organic material on irregular bedding surfaces. Numerous organic partings which are broken only with hammer. Sandstone does not break down in water; siltstone breaks down slowly to mud. Siltstone is very clayey and fractured.

11.0-29.0 SHALE: Dark gray to dark brownish gray. Silty. Fissile to very shaly. Many small slicks on clayey partings. Some Fe coatings. Locally medium grained sandstone at 15'±, with slight ferruginous cement. Non-calcareous. Moderately to poorly cemented. Shale breaks down quickly in water. Becomes highly organic (lignitic) 27-28 with some sulfur surface coating.

29.0-44.4 SANDSTONE: Light brownish gray to gray. Medium grained, subangular. Silty in upper 2'. Bedding averages 6" thick, 1.4' maximum. Many irregular finely bedded (1/4") organic Fe partings with fine selenite throughout. Some siltstone partings with fragmented organic-woody material. Does not break down readily in water. Grades into next unit.

44.4-46.6 SHALE AND COAL: Black to brownish black. Very organic fissile shale with coal. Lignite partings. Fe oxide and sulfur on partings and joints. Lignite 45-45.8. Slicks on some coal surfaces. Scattered selenite flakes. Grades to coal below lignite, up to 1.5' thick with good conchoidal fracture.

46.6-50.0 SANDSTONE AND SILTSTONE: Gray. Interbedded, fine grained. Angular to subangular quartz grains. More massive. Silty and calcareous. Silty units are very fractured, shaly, and clayey. Some thin irregular coaly seams near base. Siltstone breaks down slowly in water.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole . . . D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE EMRIA — PROJECT BLM-Hanna Basin — STATE Wyoming — SHEET 1 OF 2 — HOLE NO. MS-9006

GEOLOGIC LOG OF DRILL HOLE

FEATURE .EMRIA.......... PROJECT .BLM - Hanna Basin.......... STATE..Wyoming..........
HOLE NO. MS-9006.. LOCATION..See below.......... GROUND ELEV. .6500±......... DIP (ANGLE FROM HORIZ.)..Vertical.......
COORDS. N............... E...........
BEGUN ..8-6-74... FINISHED..8-19-74..... TOTAL DEPTH..100.0... BEARING...--..........
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED...See below.............. LOGGED BY.Johnson-Bennett...... LOG REVIEWED BY. N. B. Bennett, III....

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	SUITABILITY OF OVERBURDEN: DEPTH (FEET) FROM (P, Cs, or Cm)	TO	SUITABLE	DOUBTFUL	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
												50.0-51.0 SHALE: Black, very fissile. Very thin coaly partings. Soft. Grades into units above and below. Breaks down in water into fissile flakes.
	10								10			51.0-52.2 SANDSTONE: Fine-grained, light to dark gray with irregular partings and carbonaceous woody fragments. Thin to moderately bedded (25") grading into shale in lower 0.4'. Non-calcareous.
	20								20			52.2-53.5 SHALE: Gray. Fissile to blocky. Scattered carbonaceous material and small coal chunks. Disaggregates rapidly in water. Hardness 4. No HCl reaction.
	30								30			53.5-58.3 COAL: Grading into lignite, shale and coal again. Thin bedded to blocky. Few slickensided surfaces. Metallic-yellow flecks at 58'. Scattered HCl reactions:
	40								40			58.3-98.6 SILTSTONE AND SANDSTONE: Gray Scattered coaly and carbonaceous pods. No HCl reaction. Very slight breakdown in water. Blocky. Broken along near vertical joint 60-60.5. Slickenside at 83.5. Hardness 5. Sandstone at 60.5-61.1 and 84.9-88.6: Both very fine-grained, no HCl reaction, light gray. Lower ss has 75° to vertical joints, carbonaceous material on bedding planes, very slight HCl reaction, 2" thick bedding, hardness 6.
	50								50			
	60								60			98.6-100.0 SHALE: With some mudstone. 1/4" to 1/2" thick bedding to blocky. Some carbonaceous material. Breaks down slowly in water. Slicked at 99.6 Portions appear to have air desiccated Gray.
	70								70			
	80								80			
	90								90			

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole .... D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series). . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 3

FEATURE: Energy Mineral Rehabilitation Inventory and Analysis — PROJECT: BLM - Hanna Basin — STATE: Wyoming

HOLE NO. MS-9007 — LOCATION: See below — GROUND ELEV. 6545± — DIP (ANGLE FROM HORIZ.): Vertical

COORDS. N. -- E. --

BEGUN 7-10-74 — FINISHED 8-2-74 — TOTAL DEPTH 106.3 — BEARING --

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: See below — LOGGED BY: R. B. Johnson — LOG REVIEWED BY: N. B. Bennett, III

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Drilled with Failing 1500 truck mounted drill rig.

Drilled with air. 0-100.3, water 100.3-106.3

NQ wireline and D-core 0-106.3.

Rock bitted to 19.1 and set 4" Cs.

Water Levels

Depth	Date
68.4 (mud)	7-22-74
73.4 "	7-23-74
92.5 "	7-24-74
93.6 "	7-25-74
95.7 "	7-26-74
91.9 (water)	7-27-74
96.6 "	7-29-74
97.9 "	7-30-74

Note: First five readings correspond with hole depth at beginning of shift.

Hole located 400' S 45° W of

31	32
6	5

Section corner in section 6, R 83 W, T 23 N.

TYPE AND SIZE OF HOLE

4" Cs (0-19.1); NQ (19.1-106.3)

CORE RECOVERY (%)

65, 100, 45, 0, 50, 53, 7, 40, 43, 91, 65, 100, 100, 80, 84, 100, 100, 100, 100, 98, 100, 80, 68, 86, 86, 47, 70, 100, 90, 97, 76

ELEVATION AND DEPTH (FEET)

Elevation	Depth
6539.2	5.8
6530.8	14.2
6528.4	16.6
6520.5	24.5
6516.0	29.0
6514.8	30.2
6509.5	35.5
6489.9	55.1
6488.7	56.3
6480.0	65.0
6478.2	66.8
6462.5	82.5
6461.9	83.1
6460.0	85.0
6451.5	93.5

CLASSIFICATION AND PHYSICAL CONDITION

Overburden - 0-5.8 feet

0.0-5.8 SILT: Sandy, light tan, sand sized material quartz, very friable, very calcareous. More cohesive, less calcareous, moderately organic near surface.

Ferris Fm. 5.8-106.3 feet

5.8-14.2 SANDSTONE: Light to yellowish brown, coarse grained, subangular quartz, silty, slightly clayey, slightly calcareous. Hardness 7. Bedding moderately developed. Slight Mn staining on joint surfaces. Does not break down in water.

14.2-16.6 SANDSTONE: Light gray to light brown, medium to fine grained angular to subangular quartz, very silty, slightly clayey, moderately to very calcareous. Hardness 7. Bedding 1.5-3.0". Slight to moderate Mn staining on joints. Thin, poorly cemented clayey, silty seams with some organics in lower 0.6'. Increase in iron oxide in matrix in lower 0.8'. Gradational with underlying unit. Does not break down in water.

16.6-24.5 SILTSTONE: Gray to brownish black, mottled, sandy, locally shaly, slightly calcareous. Hardness 2-4. Irregularly bedded. Random selenite gypsum crystals up to 1/4". Much organic material. Breaks down readily in water.

24.5-29.0 SHALE AND COAL: Shale, brown-gray to black, silty, fissile, intergrades with thin (1/8-1-1/2") coal. Bedding well defined with woody material on surfaces. Sulfur and small selenite crystals throughout on bedding and joints. Shale slickensided in upper 1.0'. Coal predominates in lower 1.0'. Unit breaks down readily in water.

29.0-30.2 SANDSTONE: Light gray, fine grained, angular to subangular quartz, slightly to moderately calcareous, silty. Hardness 7. Thin to massive (3") bedding, with irregular thin seams of organic material, locally grading to coal (1/8"). Grades into underlying unit. Does not break down in water.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole . . . D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE EMRIA — PROJECT BLM-Hanna Basin — STATE Wyoming — SHEET 1 OF 3 — HOLE NO. MS-9007

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 3

FEATURE: Energy Mineral Rehabilitation Inventory and Analysis — PROJECT: BLM - Hanna Basin — STATE: Wyoming

HOLE NO. MS-9007 — LOCATION: See below — COORDS. N. -- E. -- — GROUND ELEV. 6545± — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 7-10-74 — FINISHED: 8-2-74 — TOTAL DEPTH: 106.3 — BEARING: --

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: See below — LOGGED BY: R. B. Johnson — LOG REVIEWED BY: N. B. Bennett, III

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET) FROM (P, Cs, or Cm)	DEPTH (FEET) TO	SUITABILITY OF OVERBURDEN: SUITABLE	DOUBTFUL	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
	NQ	65						6444.7	100.3			
		90						6438.7	106.3			

30.2-35.5 COAL AND SHALE: Coal ranging up to 2" with conchoidal fracture. Grades into shaly coal and organic, silty black shale with fissile bedding. Coal locally has slickensides. Breaks down slowly in water into flaky, coaly material.

35.5-55.1 SILTSTONE AND MUDSTONE: Light gray, flaggy to massive bedding (1.2' max.). Hardness 4-5. Bedding poorly developed with scattered irregular partings with organic coating, locally woody, one well-defined leaf. Breaks down slowly in water. (Should be checked petrographically for ash.)

55.1-56.3 SHALE AND COAL: Shale, black, silty, fissile, very organic with coal partings up to 2" thick. Some slickensides on coal. Breaks down readily in water.

56.3-65.0 SILTSTONE AND MUDSTONE: As in 35.5-55.1' zone. Beds up to 1' thick. Hardness 4-7. Slightly to moderately calcareous, slightly to very clayey. Leaves on bedding surfaces. Breaks down slowly in water.

65-66.8 SHALE: Gray, thin shaly to fissile partings leaving fractured appearance. Organics limited to bedding surfaces and consist of common to local woody pieces. Hardness 5-6. Dense and not easily disaggregated in water.

66.8-82.5 SILTSTONE TO MUDSTONE: Mainly locally shaly. Bedding more noticeable. Becomes more clayey at 73.5'. Clayey zones break down in water at 74, 79, and 82.

82.5-83.1 SHALE: Dark gray to black. Silty. Fissile to very shaly partings. Organics throughout shale but not on partings. Breaks down into fissile flakes in water but does not truly disaggregate.

83.1-85.0 SILTSTONE: Gray. Very clayey. Not calcareous. Organics very dense. Hardness 6-7. Mottled. Slight surface disaggregation into silty mud. Core in 1-2" lengths.

EXPLANATION

CORE LOSS

CORE RECOVERY

Type of hole . . . . D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: EMRIA — PROJECT: BLM-Hanna Basin — STATE: Wyoming — SHEET 2 OF 3 — HOLE NO. MS-9007

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

FEATURE Energy Mineral Rehabilitation Inventory and Analysis PROJECT BLM - Hanna Basin STATE Wyoming

HOLE NO. MS-9007 LOCATION See below COORDS. N. -- E. -- GROUND ELEV. 6545± DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 7-10-74 FINISHED 8-2-74 TOTAL DEPTH 106.3 BEARING --

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See below LOGGED BY R. B. Johnson LOG REVIEWED BY N. B. Bennett, III

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	DEPTH (FEET) FROM (P, Cs, or Cm)	TO	SUITABILITY OF OVERBURDEN: SUITABLE	DOUBTFUL	UNSUITABLE	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
												85.0-93.5 SHALE AND COAL: Dark gray to black. Fissile. Noncalcareous shale with coal partings. Slightly silty. Up to 1" pieces.
												93.5-100.3 SILTSTONE AND SANDSTONE: Gray sandy siltstone in upper 1' grading to silty fine-grained sandstone, all slightly to moderately clayey. Noncalcareous. Sandstone angular to subangular quartz in silt-clay matrix. Irregular partings. Organic coatings on siltstone partings, not as common in sandstone but locally giving mottled appearance. Core pieces up to .5' but mostly 1-2". Hardness 5-6. Does not disaggregate readily in water.
												100.3-106.3 SHALE: Dark gray to black. Fissile to very shaly. Numerous slickensided coal partings in upper 2.5'. Becoming less fissile and more fragmented (1/8 - 1/2") in lower 1.5'. Upper shale quickly disaggregates into fine fissile flakes in water. Lower shale readily disaggregates into silty mud.
												TOTAL DEPTH - 106.3

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole . . . D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx - 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE EMRIA PROJECT BLM-Hanna Basin STATE Wyoming SHEET 3 OF 3 HOLE NO. MS-9007

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE: EMRIA — PROJECT: BLM-Hanna Basin — STATE: Wyoming

HOLE NO.: MS-9008 — LOCATION: See below

COORDS. N. ____ E. ____ — GROUND ELEV.: 6450 ± — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 9/4/74 — FINISHED: 9/9/74 — TOTAL DEPTH: 203.5 — BEARING: ————

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: See below — LOGGED BY: N.B.Bennett, III — LOG REVIEWED BY: N.B. Bennett, III

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Drilled with Failing 1500 truck mounted drill rig.

Drilled with water 0-38.2, 82.9-153.5, 192.2-203.5.

Drilled with Revert 38.2-82.9, 153.5-192.2.

Lost circulation at 35.0, no return.

NQ core 0-203.5.

This hole was originally numbered MS-9012.

Hole located about 500 ft. N 45° E of

11	12
14	13

in Section 12, R 84 W, T 23 N.

Water Levels

Date	Hole Depth	Water Level
9-6	82.9	74.0
9-7	137.2	81.9
9-9	192.2	81.9

TYPE AND SIZE OF HOLE: Nq

CORE RECOVERY (%): 57, 29, 30, 19, 62, 100, 100, 83, 87, 98, 98, 87, 62, 100, 100, 97, 91, 97

ELEVATION (FEET) / DEPTH (FEET):

Elevation	Depth
6447.0	3.0
6442.6	7.4
6428.6	21.4
6426.5	23.5
6426.0	24.0
6420.2	29.8
6417.3	32.7
6416.5	33.5
6401.7	48.3
6397.1	52.9
6382.4	67.6
6379.6	70.4
6376.4	73.6
6373.5	76.5
6367.3	82.7
6365.6	84.4
6360.9	89.1

CLASSIFICATION AND PHYSICAL CONDITION

0 - 3.0 Surficial Soil Deposits

0 - 3.0 Silt, Sandy. Sandstone fragments increasing with depth. Tan to rusty. Calcareous.

3.0- 7.4 Sandstone. Fine to medium grained. Weathered. Spotty HCl reaction. Tan to rusty. 1" to 2" fragments.

7.4-21.4 Siltstone. Fine sandy. Shaley near bottom. Fe stains throughout. None to slight HCl reaction. Weathered. Very slow breakdown in water. Few-6" sandstone layers. 1"-3" pieces. Hardness 5-6.Tan to rusty.

21.4-23.5 Shale & Mudstone. Thin bedded to blocky. Fe stained throughout. Scattered gypsum crystals. Minute carbonaceous banding. No HCl reaction. Very slow breakdown in water. Gray.

23.5-24 Sandstone. Medium grained.

24 -29.8 Siltstone & Shale. 2" to 7" pieces. No HCl reaction. Rusty-tan. Shale at 27.6-29.8, black.

29.8-32.7 Sandstone. Medium coarse grained. Slightly friable. Joint at bottom. Tan with Fe spots.

32.7-33.5 Shale. Thin bedded to fragmented. Most of core is missing.

33.5-48.3 Siltstone. Carbonaceous banding. Fe stains on most breaks.Shaley 42.1-42.5.Some FeO banding.Hardness 6. Light to dark gray.

48.3-52.9 Shale. Carbonaceous. Thin bedded to fissile. Coaly 49.6-52. Hardness 5. Black to dark gray. Grades into next unit.

52.9-67.6 Sandstone. Siltstone and shaley layers. Fine to medium grained. Carbonaceous banding and pods. No HCl reaction. 2 jointed areas. Gray.

67.6-70.4 Siltstone. Fragments to 8" pieces. 30° dipping joint at bottom contact.Shaley 67.9-68.4. Gray.

70.4-73.6 Sandstone. Fine grained quartz with fine mica. Carbonaceous banding. Silty. No HCl reaction. Several joints. Light gray.

73.6-76.5 Siltstone. Black carbonaceous banding increasing with depth. No HCl reaction. Gray.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE EMRIA — PROJECT BLM-Hanna Basin — STATE Wyoming — SHEET 1 OF 2 — HOLE NO. MS-9008

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

FEATURE: EMRIA — PROJECT: BLM-Hanna Basin — STATE: Wyoming

HOLE NO.: MS-9008 — LOCATION: See below — COORDS. N. ... E. ... — GROUND ELEV.: 6450± — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 9/4/74 — FINISHED: 9/9/74 — TOTAL DEPTH: 203.5 — BEARING: ———

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: See below — LOGGED BY: N.B. Bennett, III — LOG REVIEWED BY: N.B. Bennett, III

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	ELEVATION (FEET)	DEPTH (FEET)
	Nq	100, 97, 100, 100, 100, 100, 100, 90, 100, 100, 90, 99, 100, 100, 100, 93, 100, 100	6346.8	103.2
			6345.4	104.6
			6338.5	111.5
			6325.9	124.1
			6315.1	134.9
			6283.2	166.8
			6246.5	203.5

SUITABILITY OF OVERBURDEN: SUITABLE / DOUBTFUL / UNSUITABLE

CLASSIFICATION AND PHYSICAL CONDITION

76.5- 82.7 Coal. Sample taken.

82.7- 84.4 Shale & Mudstone. Coaly near top. Thin bedded to fragments. Black to gray.

84.4- 89.1 Siltstone. Thin carbonaceous zones and banding. Hardness 6. Light gray. Grades into next interval.

89.1-103.2 Sandstone. Fine grained. Black carbonaceous banding near top. Composed of quartz with fine mica. Mostly silty but some calcareous zones. Massive. Slightly friable and porous. Hardness 6. Light gray.

103.2-104.6 Shale. Carbonaceous slickenside at 103.7. Black.

104.6-111.5 Coal. Highly carbonaceous shale at top. Sample taken 104.9-111.5.

111.5-124.1 Sandstone. Fine grained. Carbonaceous banding increasing with depth. Quartz with mica. Carbonaceous shaley siltstone 116.9-118.5. 4" to 1.5' pieces. Light gray. Grades into next interval.

124.1-134.9 Shale & Mudstone. Thin bedded to fissile to fragmented. Scattered slickensides. Very slow breakdown in water. Coal fragments 132.5 & 134.2. Hardness 5-6. Dark gray to black.

134.9-166.8 Siltstone. Fine sandy. Increasing carbonaceous matter toward bottom. No HCl reaction except slight 162.8-166.8. 30° dipping joints at 140.2 & 153.4. Excellent core with pieces up to 3' long. Gray to dark gray.

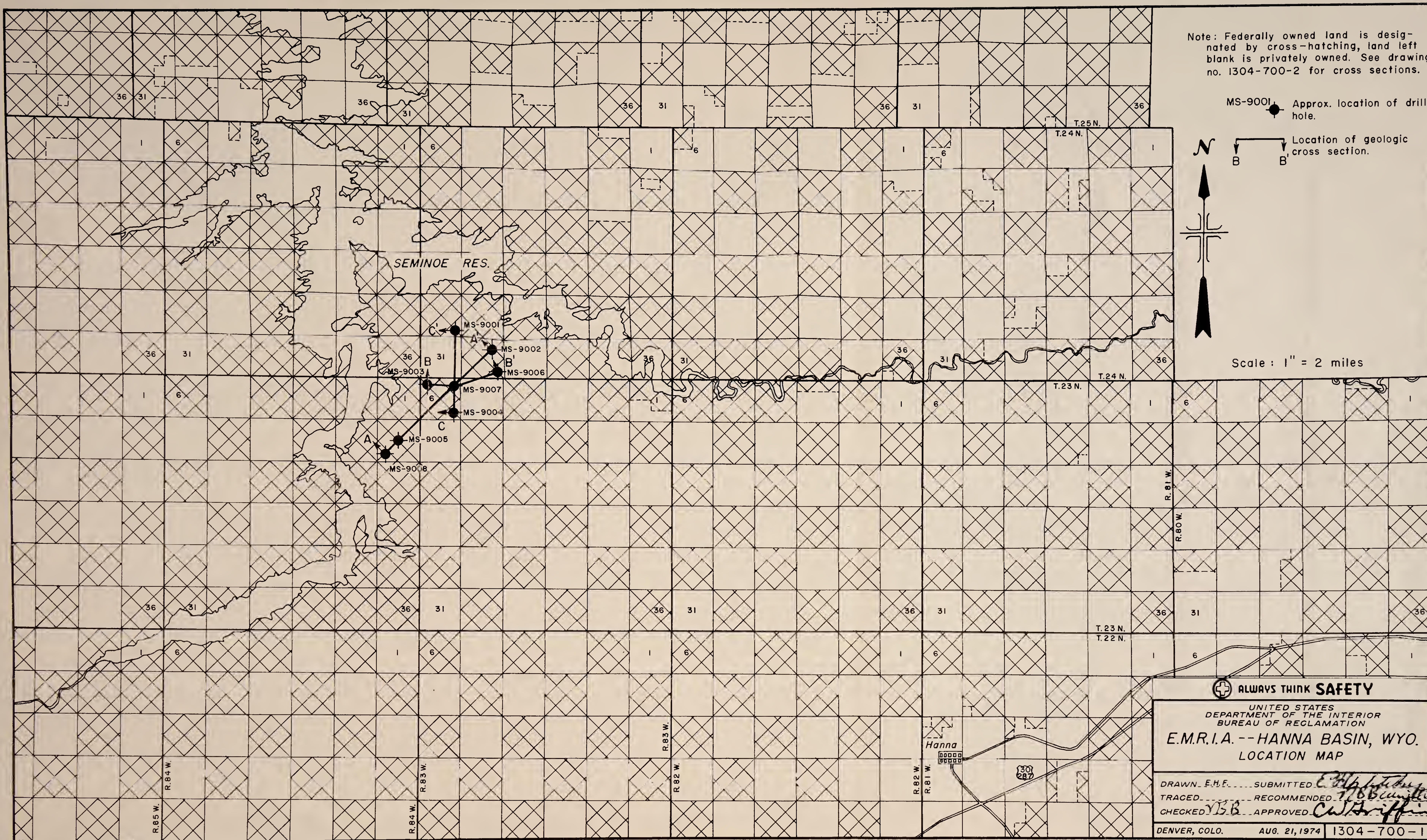
166.8-203.5 Sandstone. Fine grained. Slightly friable. Carbonaceous and micaceous banding. -1/2" coal seams 192.8-193.5 and 201.5. Excellent core with pieces up to 4' long. Light gray.

Total depth 203.5

CORE LOSS / CORE RECOVERY

Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series).. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: EMRIA — PROJECT: BLM-Hanna Basin — STATE: Wyoming — SHEET 2 OF 2 — HOLE NO. MS-9008



Note: Federally owned land is designated by cross-hatching, land left blank is privately owned. See drawing no. 1304-700-2 for cross sections.
MS-9001 Approx. location of drill hole.
B B' Location of geologic cross section.
N
Scale : 1" = 2 miles
SEMINOE RES.
MS-9001
MS-9002
MS-9003
MS-9004
MS-9005
MS-9006
MS-9007
MS-9008
A
A'
B
B'
C
C'
T.25 N.
T.24 N.
T.23 N.
T.22 N.
R.85 W.
R.84 W.
R.83 W.
R.82 W.
R.81 W.
R.80 W.
Hanna
30
287
ALWAYS THINK SAFETY
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
E.M.R.I.A.--HANNA BASIN, WYO.
LOCATION MAP
DRAWN E.H.F. SUBMITTED
TRACED RECOMMENDED
CHECKED APPROVED C W Griffin
DENVER, COLO. AUG. 21, 1974 1304-700-1

Plate 2

Coal

Origin

Coal has been defined as "a readily combustible rock containing more than 50 percent by weight and more than 70 percent by volume of carbonaceous material, formed from compaction or induration of variously altered plant remains similar to those of peaty deposits. Differences in the kinds of plant materials (type), in degree of metamorphism (rank), and range of impurity (grade), are characteristics of the varieties of coal" (Schopf, 1956). Inherent in the definition is the specification that the coal originated as a mixture of organic plant remains and inorganic mineral matter that accumulated in a manner similar to that in which modern day peat deposits are formed. The peat then underwent a long, extremely complex process called "coalification" during which diverse physical and chemical changes occurred as the peat changed to coal, and the coal assumed the characteristics by which we differentiate members of the series from each other. The factors that affect the composition of coals have been summarized by Francis (1961, p. 2) as follows:

1) The mode of accumulation and burial of the plant debris forming the deposits.

2) The age of the deposits and their geographical distribution.

3) The structure of the coal-forming plants, particularly details of structure that affect chemical composition or resistance to decay.

4) The chemical composition of the coal-forming debris and its resistance to decay.

5) The nature and intensity of the plant-decaying agencies.

6) The subsequent geological history of the residual products of decay of the plant debris forming the deposits.

For extended discussions of these factors, the reader is referred to such standard works as Moore (1940), Lowry (1945), Tomkeieff (1954), Francis (1961), and Lowry (1963).

Classification

Coals can be classified in many ways (Tomkeieff, 1954, p. 9; Moore, 1940, p. 113; Francis, 1961, p. 361), but the classification by rank--that is, by degree of metamorphism in the progressive series

which begins with peat and ends with graphocite (Schopf, 1966)--is the most commonly used system. Classification by types of plant materials is commonly used as a descriptive adjunct to rank classification when sufficient megascopic and microscopic information is available, and classification by type and quantity of impurities (grade) is also frequently used when utilization of the coal is being considered. Other categorizations are possible and are commonly employed in discussion of coal resources--such factors as the weight (specific gravity) of the coal, the thickness and areal extent of the individual coal beds, and the thickness of overburden are generally considered.

Rank of coal

The designation of a coal within the metamorphic series, which begins with peat and ends with graphocite, is dependent upon the temperatures and pressure to which the coal has been subjected and the duration of time of subjection. Because it is by definition largely derived from plant material, coal is mostly composed of carbon, hydrogen, and oxygen, along with smaller quantities of nitrogen, sulfur, and other elements. The increase in rank of coal as it undergoes progressive metamorphism is indicated by changes in the proportions of the coal constituents--the higher rank coals have more carbon and less hydrogen and oxygen than the lower ranks. Two standardized forms of coal analyses--the proximate analysis and the ultimate analysis--are generally used in the world today, though sometimes only the less complicated and less expensive proximate analysis is made. The analyses are described as follows (U.S. Bur. Mines, 1965, p. 121-122):

> "The proximate analysis of coal involves the determination of four constituents: (1) water, called moisture; (2) mineral impurity, called ash, left when the coal is completely burned; (3) volatile matter, consisting of gases or vapors driven out when coal is heated to certain temperatures; and (4) fixed carbon, the solid or cake-like residue that burns at higher temperatures after volatile matter has been driven off. Ultimate analysis involves the determination of carbon and hydrogen as found in the gaseous products of combustion, the determination of sulfur, nitrogen, and ash in the material as a whole, and the estimation of oxygen by difference."

Most coals are burned to produce heat energy so the heating value of the coal is an important property. The heating value (calorific value) is commonly expressed in British thermal units (Btu) per pound; 1 Btu is the amount of heat required to raise the temperature of 1 lb of water 1^{o}F (in the metric system, heating value is expressed in kilogram-calories per kilogram). Additional tests are sometimes made, particularly to determine the caking, coking, and other properties, such as tar yield, which affect classification

or utilization.

Figure 2 compares in histogram form the heating value and moisture, volatile matter, and fixed carbon contents of coals of different ranks.

Various schemes for classifying coals by rank have been proposed and used but the most commonly employed are the "Standard specifications for classification of coals by rank," adopted by the American Society for Testing and Materials - 1974, table 1.

The ASTM classification system differentiates coals into classes and groups on the basis of mineral-matter-free fixed carbon or volatile matter and the heating value supplemented by determination of agglomerating (caking) characteristics. "Coals which in the volatile matter determination produce either an agglomerate button that will support a 500-g weight without pulverizing, or a button showing swelling or cell structure, shall be considered agglomerating from the standpoint of classification (ASTM, 1974, p. 56)".

As pointed out by the ASTM (1974, p. 55), a standard rank determination cannot be made unless the samples were obtained in accordance with standardized sampling procedures (Snyder, 1950; Schopf, 1960). However, nonstandard samples may be used for comparative purposes through determinations designated as "apparent rank."

The moist, mineral-matter-free calorific values, in Btu per pound, determined for the coal samples listed in table 2, and the corresponding apparent rank determination, are as follows:

Sample number	Moist, mineral-matter-free Btu	Rank
D169597	10,820	High volatile C, bituminous or subbituminous A
D169598	11,990	High volatile C bituminous
D169599	11,570	High volatile C bituminous
D169607	11,500+	High volatile C bituminous
D169608	11,460	High volatile C or subbituminous A

No information on agglomerating characteristics is available for these samples. As pointed out by Glass (1972, p. 4 and 5), the coals of the Hanna Basin range through the high-volatile C bituminous and subbituminous A coal groups. The range in degree of metamorphism of the Hanna Basin coals is still undefined.

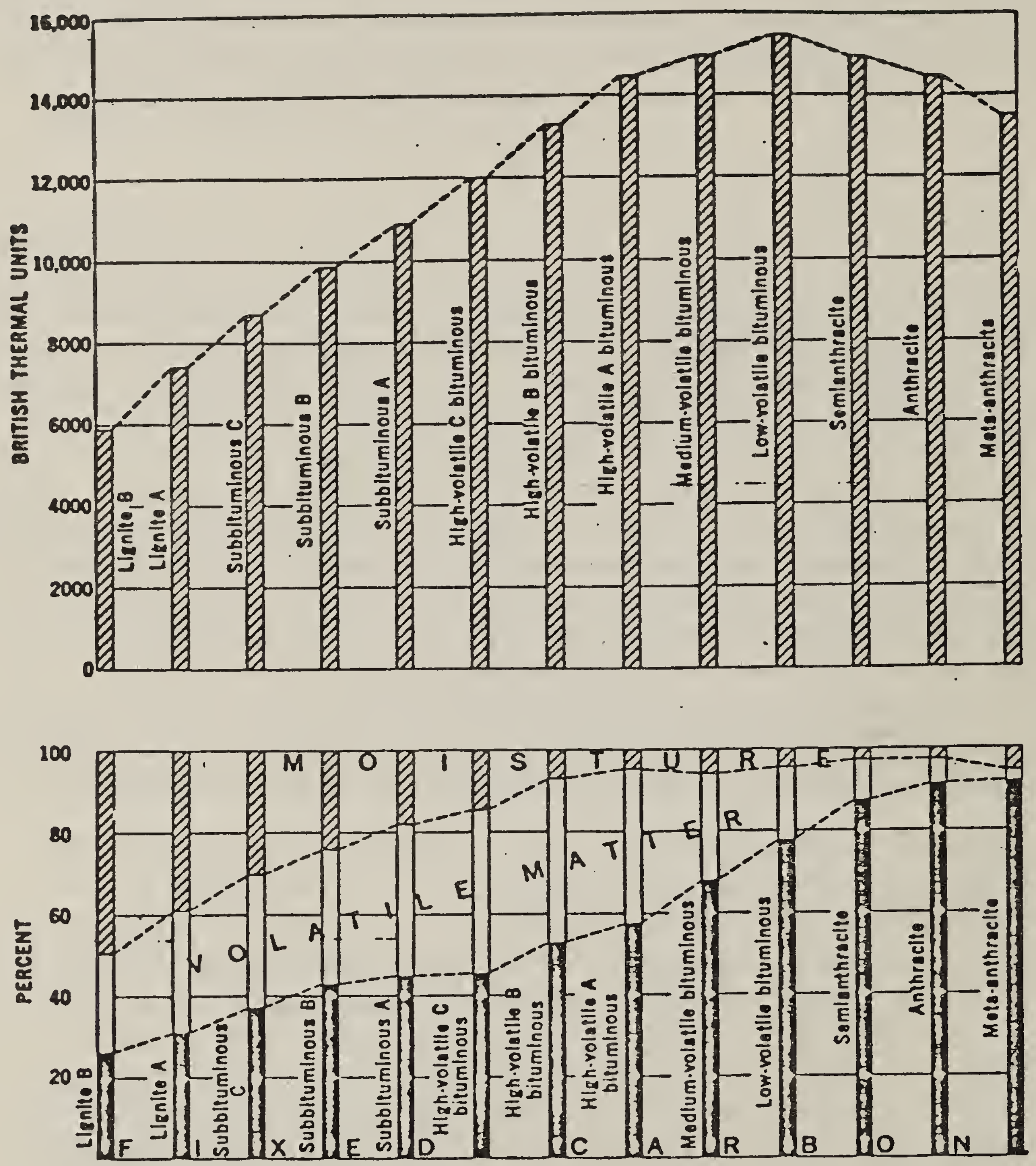


Figure 2.--Comparison on moist, mineral-matter-free basis of heat values and proximate analyses of coal of different ranks.

Table 1--Classification of coals by rank[1]
[American Society for Testing and Materials Standard D388-66 (Reapproved 1972)]

Class	Group	Fixed Carbon Limits, percent (Dry, Mineral-Matter-Free Basis)		Volatile Matter Limits, percent (Dry, Mineral, Matter-Free Basis)		Calorific Value Limits, Btu per pound (Moist,[2] Mineral-Matter-Free Basis)		Agglomerating Character
		Equal or Greater Than	Less Than	Greater Than	Equal or Less Than	Equal or Greater Than	Less Than	
I. Anthracite	1. Meta-anthracite	98	...	...	2	...	...	nonagglomerating
	2. Anthracite	92	98	2	8	...	...	nonagglomerating
	3. Semianthracite[3]	86	92	8	14	...	...	nonagglomerating
II. Bituminous	1. Low volatile bituminous coal	78	86	14	22	...	...	Commonly agglomerating[5]
	2. Medium volatile bituminous coal	69	78	22	31	...	...	Commonly agglomerating[5]
	3. High volatile A bituminous coal	...	69	31	...	14 000[4]	...	Commonly agglomerating[5]
	4. High volatile B bituminous coal	...	...	...	...	13 000[4]	14 000	Commonly agglomerating[5]
	5. High volatile C bituminous coal	...	...	...	...	11 500	13 000	Commonly agglomerating[5]
						10 500	11 500	agglomerating
III. Subbituminous	1. Subbituminous A coal	...	...	...	...	10 500	11 500	nonagglomerating
	2. Subbituminous B coal	...	...	...	...	9 500	10 500	nonagglomerating
	3. Subbituminous C coal	...	...	...	...	8 300	9 500	nonagglomerating
IV. Lignitic	1. Lignite A	...	...	...	...	6 300	8 300	nonagglomerating
	2. Lignite B					...	6 300	nonagglomerating

[1]This classification does not include a few coals, principally nonbanded varieties, which have unusual physical and chemical properties and which come within the limits of fixed carbon or calorific value of the high-volatile bituminous and subbituminous ranks. All of these coals either contain less than 48 percent dry, mineral-matter-free fixed carbon or have more than 15,500 moist, mineral-matter-free British thermal units per pound.

[2]Moist refers to coal containing its natural inherent moisture but not including visible water on the surface of the coal.

[3]If agglomerating, classify in low-volatile group of the bituminous class.

[4]Coals having 69 percent or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of calorific value.

[5]It is recognized that there may be nonagglomerating varieties in these groups of the bituminous class, and there are notable exceptions in high volatile C bituminous group.

Table 2.--Proximate, ultimate, Btu and forms of sulfur analyses of five samples from the Hanna Basin, Carbon County, Wyoming. (All analyses except Btu are in percent. Original moisture content may be slightly more than shown because samples were collected and transported in plastic bags to avoid metal contamination. Form of analyses: A, as received; B, moisture free; C, moisture and ash free. All analyses by Coal Analysis Section, U.S. Bureau of Mines, Pittsburgh, Pa.)

		PROXIMATE ANALYSIS				ULTIMATE ANALYSIS						FORMS OF SULFUR		
Sample No.	Form of Analysis	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Btu Value	Sulfate	Pyritic	Organic
Shot-pile sample, Seminoe No. 1 Mine, Ferris Formation of Paleocene age, No. 24 bed, 21 ft thick, SW1/4, sec. 7, T. 22 N., R. 83 W.														
D169597	A	10.5	35.8	49.5	4.2	5.0	62.1	0.9	27.5	0.3	10,330	0.01	0.14	0.17
	B	--	40.0	55.3	4.7	4.3	69.4	1.0	20.3	.3	11,550	.01	.15	.19
	C	--	42.0	58.0	--	4.5	72.8	1.0	21.3	.4	12,110	.01	.16	.19
Composite core bench sample, drill hole 8, Ferris Formation of Paleocene age, unnamed bed, depth 77.3 - 82.7 ft, SW1/4SW1/4SW1/4, sec. 12, T. 23 N., R. 83 W.														
D169607	A	12.6	36.7	45.3	5.4	5.6	62.9	1.3	24.2	0.6	10,820	0.02	0.25	0.36
	B	--	42.0	51.8	6.2	4.8	72.0	1.5	14.8	.7	12,380	.02	.28	.41
	C	--	44.8	55.2	--	5.2	76.8	1.6	15.6	.8	13,200	.02	.30	.44
Composite core bench sample, drill hole 8, Ferris Formation of Paleocene age, unnamed bed, depth 104.9 - 111.5 ft, SW1/4SW1/4SW1/4, sec. 12, T. 23 N., R. 83 W.														
D169608	A	11.2	30.9	44.8	13.1	5.1	58.3	1.1	22.1	0.3	9,840	0.02	0.11	0.16
	B	--	34.8	50.4	14.8	4.4	65.6	1.2	13.7	.3	11,070	.02	.12	.18
	C	--	40.8	59.2	--	5.1	77.0	1.5	16.0	.4	12,990	.03	.14	.22
Shot-pile sample, Seminoe No. 2 Mine, Hanna Formation of Paleocene age, Hanna No. 2 bed, 33 ft thick, SW1/4, sec. 4, T. 22 N., R. 81 W.														
D169598	A	10.7	38.5	40.5	10.3	5.7	59.6	1.3	22.4	0.7	10,650	0.01	0.25	0.46
	B	--	43.1	45.4	11.5	5.0	66.8	1.4	14.5	.8	11,920	.01	.28	.52
	C	--	48.7	51.3	--	5.7	75.4	1.6	16.4	.9	13,470	.01	.32	.58
Tipple (off-belt) sample, Rosebud No. 4A Mine, Hanna Formation of Paleocene age, No. 82 bed, 25 ft thick including 1 ft clay parting and No. 80 bed 10 ft thick, sec. 9, T. 21 N., R. 81 W.														
D169599	A	12.1	36.2	41.9	9.8	5.7	58.8	1.4	23.4	0.9	10,330	0.02	0.27	0.63
	B	--	41.1	47.8	11.1	4.9	66.9	1.6	14.5	1.0	11,740	.02	.31	.71
	C	--	46.3	53.7	--	5.6	75.2	1.8	16.2	1.2	13,210	.02	.35	.80

Because of the lack of definitive information about the distribution of coals of various ranks in the Hanna Basin, the coal in the area of this study is considered to be in the subbituminous class for purposes of resource evaluation.

Type of coal

Classification of coals by type--that is, according to the types of plant materials present--takes many forms, such as the "rational analysis" of Francis (1961), or the semicommercial "type" classification commonly used in the coal fields of the eastern United States (U.S. Bur. Mines, 1965, p. 123). However, most of the type classifications are based on the same, or similar, gross distinctions in plant material used by Tomkeieff (1954, table II, and p. 9), who divided the coals into three series: humic coals, humic-sapropelic coals, and sapropelic coals, based upon the nature of the original plant materials. The humic coals are largely composed of the remains of the woody parts of plants and the aspropelic coals are largely composed of the more resistant waxy, fatty, and resinous parts of plants, such as cell walls, spore-coatings, pollen, resin particles, and algae. Most coals fall into the humic series, with some coals being mixtures of humic and sapropelic elements and, therefore, falling into the humic-sapropelic series. The sapropelic series is quantitatively insignificant and when found is commonly regarded as an organic curiosity.

In common with most coals of the United States, the Hanna Basin coals fall largely in the humic series.

Grade of coal

Classification of coal by grade, or quality, is based largely on the content of ash, sulfur, and other constituents that adversely affect utilization. Most detailed coal resource evaluations of the past do not categorize known coal resources by grade but coals of the United States have been classified by sulfur content in a gross way (DeCarlo and others, 1966) because of the relations between the sulfur content of fuels and air pollution in heavily populated and industrialized areas.

The range and average of the ash and sulfur contents of 642 coals from all parts of the United States was determined by Fieldner, Rice, and Moran (1942).

Ash and sulfur contents of United States coals

Number of samples	Ash, percent		Sulfur, percent	
	Range	Average	Range	Average
642	2.5 - 32.6	8.9	0.3 - 7.7	1.9

The ash and sulfur contents of the five Hanna Basin coal samples, as determined by the Bureau of Mines analyses, is: ash - range 4.2 to 13.1 percent, average 8.6 percent; sulfur - range 0.3 to 0.9 percent, average 0.6. The Hanna Basin coals are near the national average in ash content but have considerably less sulfur than the national average and would be classed as low-sulfur coals.

Estimation and classification of coal resources

Preparation of a coal resource estimate involves certain procedures and definitions that have been established in an attempt to standardize, insofar as possible, coal resource appraisals in the United States. As used in this report, the term "coal resource" designates the estimated quantity of coal in the ground in such form that economic extraction is currently or potentially feasible.

Tabulation of estimated coal resources

Tables 3 and 4 summarize the estimated coal resources of the Hanna Basin EMRIA site-about 3.7 square miles--and of a larger area--about 9.6 square miles-that is composed of the EMRIA site proper and adjoining areas. Table 5 lists the estimated resources of the area in a more detailed form. In accordance with agreements between the U.S. Geological Survey and the U.S. Bureau of Mines, the resources are classed as "identified-subeconomic resources"--that is, specific bodies of coal whose location, quality, and quantity are known from geologic evidence supported by engineering measurements with respect to the demonstrated category, and that are presently classed as subeconomic because the estimated tonnage of coal is in beds that are not presently classed as reserves, but may become so as a result of changes in economic and legal conditions.

That part of the estimated identified coal resources shown in tables 3, 4, and 5, that is more than 5 feet thick falls into a category

Table 3.--Summary of estimated identified coal resources of the Hanna Basin EMRIA Site. (In thousands of tons.)

	overburden thickness 0 to 100 feet	overburden thickness 100 to 200 feet	overburden thickness 0 to 200 feet
Coal beds 2 1/2 to 5 feet thick			
Demonstrated[1] resources	2,056	1,662	3,718
Inferred resources	44	--	44
Total	2,100	1,662	3,762
Coal beds 5 to 10 feet thick			
Demonstrated[1] resources	2,446	2,758	5,204
Inferred resources	--	260	260
Total	2,446	3,018	5,464
Coal beds more than 10 feet thick			
Demonstrated[1] resources	119	904	1,023
Inferred resources	--	--	--
Total	119	904	1,023
Total identified resources	4,665	5,584	10,249

[1]A collective term for the sum of coal in both measured and indicated resources.

Table 4.--Summary of estimated identified coal resources of the area around and including the Hanna Basin EMRIA Site. (In thousands of tons.)

	overburden thickness 0 to 100 feet	overburden thickness 100 to 200 feet	overburden thickness 0 to 200 feet
Coal beds 2 1/2 to 5 feet thick			
Demonstrated[1] resources	5,057	4,531	9,588
Inferred resources	157	138	295
Total	5,214	4,669	9,883
Coal beds 5 to 10 feet thick			
Demonstrated[1] resources	10,052	8,674	18,726
Inferred resources	---	260	260
Total	10,052	8,934	18,986
Coal beds more than 10 feet thick			
Demonstrated[1] resources	4,686	7,098	11,784
Inferred resources	144	415	559
Total	4,830	7,513	12,343
Total identified resources	20,096	21,116	41,212

[1]A collective term for the sum of coal in both measured and indicated resources.

Table 5.--Estimated coal resources of the area around and including the Hanna Basin EMRIA site.
(In thousands of tons.)

Thickness of overburden (feet)	2 1/2 to 5 feet thick				5 to 10 feet thick				More than 10 feet thick				Totals			
	Measured	Indicated	Inferred	Total	Measured	Indicated	Inferred	Total	Measured	Indicated	Inferred	Total	Measured	Indicated	Inferred	Total
Township 23 North, Range 83 West																
Section 5																
0 to 100	295	144	—	439	181	--	--	181	—	—	—	—	476	144	—	620
100 to 200	161	267	—	428	160	99	—	259	—	—	—	—	321	366	—	687
Total	456	411	—	867	341	99	--	440	—	—	—	—	797	510	--	1,307
Section 6 (EMRIA)																
0 to 100	366	159	—	525	295	--	—	295	—	—	—	—	661	159	—	820
100 to 200	332	179	—	511	334	75	—	409	—	—	—	—	666	254	—	920
Total	698	338	—	1,036	629	75	—	704	—	—	—	—	1,327	413	—	1,740
Township 23 North, Range 84 West																
Section 1																
0 to 100	—	—	—	--	95	312	—	407	—	—	—	--	95	312	—	407
100 to 200	—	—	—	—	7	366	--	373	—	—	—	--	7	366	—	373
Total	—	—	—	—	102	678	--	780	—	—	—	--	102	678	—	780
Section 11																
0 to 100	200	8	—	208	300	416	—	716	897	—	--	897	1,397	424	—	1,821
100 to 200	135	26	—	161	64	167	—	231	972	—	--	972	1,171	193	—	1,364
Total	335	34	—	369	364	583	--	947	1,869	—	—	1,869	2,568	617	—	3,185
Section 12 (EMRIA)																
0 to 100	313	--	--	313	555	38	—	593	—	—	—	—	868	38	—	906
100 to 200	360	--	—	360	642	41	260	943	--	—	—	—	1,002	41	260	1,303
Total	673	—	--	673	1,197	79	260	1,536	—	—	—	—	1,870	79	260	2,209
Section 13																
0 to 100	—	--	—	—	—	--	--	—	1,212	—	—	1,212	1,212	—	—	1,212
100 to 200	--	—	—	—	--	—	--	—	40	353	—	393	40	353	—	393
Total	—	—	—	—	--	—	--	--	1,252	353	—	1,605	1,252	353	—	1,605
Section 14																
0 to 100	98	—	—	98	2,003	242	--	2,245	265	109	--	374	2,366	351	—	2,717
100 to 200	110	—	—	110	1,155	176	--	1,331	186	220	—	406	1,451	396	—	1,847
Total	208	—	—	208	3,158	418	--	3,576	451	329	—	780	3,817	747	—	4,564
Township 24 North, Range 83 West																
Section 29																
0 to 100	579	72	—	651	1,886	—	--	1,886	729	530	—	1,259	3,194	602	—	3,796
100 to 200	567	119	--	686	1,500	--	--	1,500	778	539	—	1,317	2,845	658	—	3,503
Total	1,146	191	—	1,337	3,386	—	—	3,386	1,507	1,069	—	2,576	6,039	1,260	—	7,299

Table 5.--Estimated coal resources of the area around and including the Hanna Basin EMRIA site.--Continued.

Thickness of overburden (feet)	2 1/2 to 5 feet thick				5 to 10 feet thick				More than 10 feet thick				Totals			
	Measured	Indicated	Inferred	Total	Measured	Indicated	Inferred	Total	Measured	Indicated	Inferred	Total	Measured	Indicated	Inferred	Total
Township 24 North, Range 83 West, (Continued)																
Section 30 (total)																
0 to 100	249	587	44	880	18	—	—	18	136	—	—	136	403	587	44	1,034
100 to 200	88	151	—	239	—	—	—	--	433	471	—	904	521	622	—	1,143
Total	337	738	44	1,119	18	—	--	18	569	471	—	1,040	924	1,209	44	2,177
Partial Section 30, EMRIA site only--approximately south half of section																
0 to 100	249	587	44	880	18	—	—	18	119	—	—	119	386	587	44	1,017
100 to 200	88	151	—	239	—	--	—	--	433	471	--	904	521	622	—	1,143
Total	337	738	44	1,119	18	—	—	18	552	471	—	1,023	907	1,209	44	2,160
Section 31																
0 to 100	728	277	113	1,118	2,127	44	—	2,171	70	738	144	952	2,925	1,059	257	4,241
100 to 200	597	521	138	1,256	1,626	596	—	2,222	1,716	1,390	415	3,521	3,939	2,507	553	6,999
Total	1,325	798	251	2,374	3,753	640	—	4,393	1,786	2,128	559	4,473	6,864	3,566	810	11,240
Section 32 (EMRIA)																
0 to 100	—	—	—	--	888	—	—	888	—	—	—	—	888	—	—	888
100 to 200	—	—	—	—	1,292	97	—	1,389	—	—	—	—	1,292	97	—	1,389
Total	—	—	—	—	2,180	97	—	2,277	—	—	—	—	2,180	97	—	2,277
Township 24 North, Range 84 West																
Section 36 (Total)																
0 to 100	612	370	—	982	542	110	—	652	—	—	—	—	1,154	480	—	1,634
100 to 200	381	537	—	918	165	112	—	277	—	—	—	—	546	649	—	1,195
Total	993	907	—	1,900	707	222	—	929	—	—	—	—	1,700	1,129	—	2,829
Partial Section 36, EMRIA site only--approximately east one-quarter of section																
0 to 100	253	129	—	382	542	110	—	652	—	—	—	—	795	239	—	1,034
100 to 200	283	269	—	552	165	112	—	277	—	—	—	—	448	381	—	829
Total	536	398	—	934	707	222	—	929	—	—	—	—	1,243	620	—	1,863
TOTAL																
EMRIA site only--approximately 3.7 square miles																
0 to 100	1,181	875	44	2,100	2,298	148	--	2,446	119	—	—	119	3,598	1,023	44	4,665
100 to 200	1,063	599	—	1,662	2,433	325	260	3,018	433	471	—	904	3,929	1,395	260	5,584
Total	2,244	1,474	44	3,762	4,731	473	260	5,464	552	471	—	1,023	7,527	2,418	304	10,249
TOTAL--approximately 9.6 square miles																
0 to 100	3,440	1,617	157	5,214	8,890	1,162	—	10,052	3,309	1,377	144	4,830	15,639	4,156	301	20,096
100 to 200	2,731	1,800	138	4,669	6,945	1,729	260	8,934	4,125	2,973	415	7,513	13,801	6,502	813	21,116
Total	6,171	3,417	295	9,883	15,835	2,891	260	18,986	7,434	4,350	559	12,343	29,440	10,658	1,114	41,212

called Reserve Base, which is defined as that portion of the identified coal resource from which reserves are calculated. Reserves in the strict sense used here are defined as "that portion of the identified coal resource that can be economically and legally mined at the time of determination--also referred to as Recoverable Reserve. The reserve is derived by applying a recoverability factor to that component of the identified coal resource designated as the Reserve Base."

Recoverability

The recoverability factor is "the percentage of total tons of coal producible from a given area in relation to the total tonnage estimated to be in place in the ground."

Recoverability determinations can be made (1) by using mine maps, (2) from production versus reserve base estimates, or (3) by using an average factor of 50 percent (see below). All coal remaining in the ground after mining is completed is considered as lost in mining and includes coal that is (1) left to support mine roofs, (2) too thin to mine, (3) left unmined beneath rivers, lakes, highways, and legal reservations, (4) left unmined around oil, gas, water, and disposal wells, (5) left unmined as barrier pillars adjacent to mine or property boundaries, and (6) left unmined because of environmental, safety, quality, or hydrologic considerations. Coal losses incurred during cleaning and preparation are not considered when determining recoverability. Recoverability determined in existing mined areas can be projected to similar unmined areas, assuming other conditions equal, to calculate reserves from reserve base. In the U.S. recoverability in underground mining ranges from 10 to 80 percent, depending on variables such as the thickness of coal bed, security of roof and floor rock, operator, and mining method. Recoverability for strip mining is locally as great as 90 percent, but studies indicate that nationally it averages about 50 percent owing to barriers left to protect mine boundaries, to restrictions on high walls, and to restrictions about mining near lakes, streams, railroads, highways, and farmed areas.

Resources categorized by degree of geologic assurance

Three categories according to degree of geologic assurance were used in the present study:

Measured - Tonnage of coal for which estimates of the quality and quantity have been computed, within a margin of error of less than 20 percent, from sample analyses and measurements from closely spaced and geologically well-

known sample sites.

Indicated - Tonnage of coal for which estimates of the quality and quantity have been computed partly from sample analyses and measurements partly from reasonable geologic projections.

Inferred - Coal in unexplored extensions of demonstrated resources for which estimates of the quality and size are based on geologic evidence and projection.

The measured resources estimated for the Hanna Basin EMRIA site and adjoining area are within 1/4 mile of points of information; the indicated resources are contained in bodies whose inner limits are 1/4 mile from points of information and whose outer limits are within 3/4 mile of points of information; the inferred resources are contained in bodies of coal whose inner boundaries are bodies of indicated resources and whose outer boundaries are as much as, but no more than, 3 miles from points of observation. Because of the limited size and shape of the study area and the 200-foot overburden thickness limitation, the bulk of the estimated resources of the study area are relatively close to points of information. About 71 percent of the estimated resources of the study area are in the measured class, about 26 percent in the indicated class, and only 3 percent in the inferred class.

Characteristics used in resource evaluation

The coal characteristics that are commonly used in classifying coal resources are the rank, grade, and weight of the coal, the thickness and areal extent of the coal beds, and the thickness of the overburden. The rank and grade of the coal sampled as part of this study have been discussed previously.

Weight

The weight of the coal ranges considerably with differences in rank and ash content. In areas such as the Hanna Basin where true specific gravities of the coals are unknown, an average specific gravity value based on many determinations in other areas is used to express the weight of the coal for reserve estimation calculations. The average weight of subbituminous coal is taken as 1,770 tons per acre-foot--a specific gravity of 1.30.

Thickness of beds

Because of the important relation of coalbed thickness to utilization

potential, most coal resource estimates prepared by the U.S. Geological Survey are tabulated according to three thickness categories. For subbituminous coal the categories are: thin--2.5 to 5 feet; intermediate--5 to 10 feet; and thick--more than 10 feet. About 24 percent of the estimated resources of the study area are in the thin category, about 46 percent are of intermediate thickness, and about 30 percent are in the thick category. By way of comparison, Averitt (1969, fig. 5 and p. 37) shows the distribution of the estimated resources of 21 states as 44 percent in beds in the thin category, 27 percent in the intermediate category, and 29 percent in the thick category. In the EMRIA site proper, about 37 percent of the estimated resources are in the thin category, about 53 percent are in the intermediate category, and about 10 percent are in the thick category.

Coalbed thicknesses used in calculating resource estimates were derived from both isopach maps and weighted average thicknesses. Bed-thickness maps were prepared where the distribution of data allowed meaningful thickness maps but in some areas, particularly of isolated and widely spaced outcrop data, weighted average thicknesses of coalbeds in the area were derived. The total area of coal of all classes in each bed may be determined in several ways: where the continuity of the bed is well established by maps of the outcrops, mine working, drill holes, etc., as in the Pittsburgh bed of the eastern United States, the entire area of known occurrency may be taken, even though points of observation are widely spaced. Persistent beds that have been traced around a basin or spur may be considered to underlie the area enclosed by the outcrop. A length of outcrop within the thickness limits listed above is considered to establish the presence of coal of all classes in appropriately spaced belts roughly parallel to and inside the outcrop. An isolated drill hole may be considered to determine an area of coal of each class extending for an appropriate radius around the hole.

Thickness of overburden

Coal resources are commonly divided into categories based on the thickness of overburden, in feet, as follows: 0-1,000, 1,000-2,000, and 2,000-3,000. For estimates of total resources and undiscovered resources--for example, an estimate for a complete coal basinal area--a depth of 6,000 feet may be used. However, the present study in the Hanna Basin is specifically aimed at areas where the coal resources can be recovered by surface mining methods and, therefore, resources were estimated only to depths of 200 feet, a reasonable parameter that reflects the present and near future capabilities of such earth-moving equipment as drag-lines.

All of the estimated resources listed in this report are overlain

by 200 feet or less of overburden and are arranged in categories of 0 to 100 feet of overburden and 100 to 200 feet of overburden. Other criteria, such as the ratio of overburden thickness to coal thickness and the ratio of quantity of overburden usually expressed in cubic yards to weight of coal present in tons, are sometimes used to outline strippable deposits of coal.

Summary of resources

The estimated identified original coal resources with 200 feet or less of overburden in the Hanna Basin EMRIA site and adjoining area total 41,212 thousand short tons, of which 29,440 thousand tons are classed as measured resources, 10,658 thousand tons are classed as indicated resources, and 1,114 thousand tons are classed as inferred resources. Coalbeds from 2.5 to 5 feet thick make up 9,883 thousand tons of the estimated resources, beds 5 to 10 feet thick make up 18,986 thousand tons, and beds more than 10 feet thick make up 12,343 thousand tons. Measured resources in beds more than 5 feet thick and with 100 feet or less of overburden total 12,199 thousand tons.

In the EMRIA site proper, an area of about 3.7 square miles, the estimated identified original coal resources with 200 feet or less of overburden total 10,249 thousand tons. Of the total, 7,527 thousand tons are classed as measured resources, 2,418 thousand tons are classed as indicated resources, and 304 thousand tons are classed as inferred resources. Coalbeds from 2.5 to 5 feet thick make up 3,762 thousand tons of the estimated resources, beds 5 to 10 feet thick make up 5,464 thousand tons, and beds more than 10 feet thick make up 1,023 thousand tons. Measured resources in beds more than 5 feet thick and with 100 feet or less of overburden total 2,417 thousand tons.

The estimated resources presented in this report are original resources, that is, resources in the ground before the beginning of mining operations.

Trace elements

Fifteen samples of Hanna Basin coals, of which three are from operating mines and the remaining 12 from cores obtained during drilling activities in the EMRIA site proper, were analyzed for trace elements following the procedure shown on figure **3**.

As an aid in solution of problems of coal utilization, the Geological Survey Analytical Laboratories routinely provide the following analytical determinations on all samples:

1. Major composition of the ash of coal--percent ash, SiO_2,

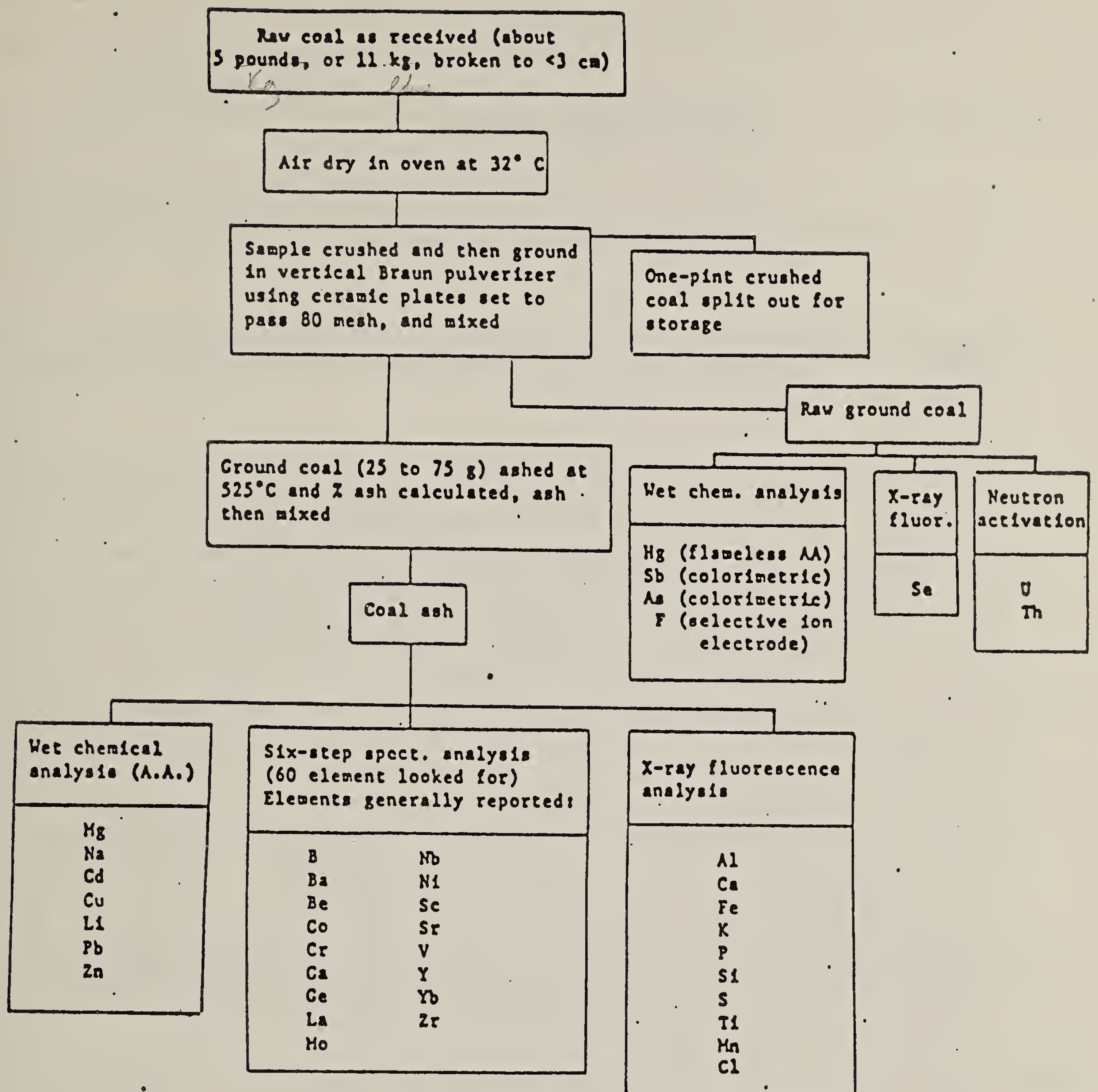


Figure 3. Sequence of sample preparation and analysis.

Al_2O_3, Na_2O, K_2O, CaO, MgO, Fe_2O_3, P_2O_5, Cl, MnO, TiO_2, and SO_3.

2. Trace element composition of coal
   a. Individual quantitative determinations--ppm As, Cd, Cu, F, Hg, Li, Pb, Sb, Se, Th, U, and Zn.
   b. Semiquantitative spectrographic analysis--ppm of 20-30 elements detected by this method.
   c. Individual quantitative determinations, of abnormal amounts indicated by semiquantitative analysis, or on spot-check basis--ppm Ag, Au, Be, Vi, Ge, Mo, Ni, Te, Tl, and V.

Results of the analytical determinations are listed here in tables 6, 7, and 8. Pertinent information about the 15 samples analyzed is present in table 9.

Swanson, Huffman, and Hamilton (1974) presented a table that shows the major differences between analyses of subbituminous coal from the Powder River Basin of Wyoming and Montana and the lignite of the Dakotas. Table 10 compares the coals of the Hanna Basin to the Northern Great Plains coals. The lesser moisture and oxygen contents and larger fixed carbon content are related to the increased degree of metamorphism (increase in rank) also shown by the greater heat value. The inorganic constituents of the Hanna Basin coals may have been derived from a source area that was closer to the depositional site of the proto-coal material than were the coals of the Northern Great Plains to their source area. The greater quartz contents of the Hanna Basin coals could be the result of such a difference in distance of transport. The greater zinc content (and perhaps antimony) may be simply related to a difference in materials being eroded from different source areas and being contributed to different depositional areas. An alternative explanation would involve slight differences in the compositions of ground water moving through the coals. The other elements listed on table 10 display no other large differences.

Table 11 shows the range of and average elemental content on the whole-coal basis, of those constituents commonly regarded as being of importance from the standpoint of utilization potential. Some of the elements, such as mercury and arsenic, are of interest because of the environmental problems that might occur if they were present in inordinate amounts; others such as uranium and zinc are of interest because they could be recovered from coal ash if they are present in sufficiently large quantities.

In comparing the average value of the elements listed in table 11 with an average value of the elements in the continental crust (Clarke value), also listed in table 11, only selenium (average

Table 6.--Major and minor oxide and trace element compositiion of the laboratory ash of fifteen samples from the Hanna Basin, Wyoming. (Values are in either percent or parts per million. The coals were ashed at 525°C. L after a value means less than the value shown. N means not detected, and B means not determined. S after the element title means that the values listed were determined by semiquantitative spectrographic analysis. The spectrographic results are to be identified with geometric brackets whose boundaries are 1.2, 0.83, 0.56, 0.38, 0.26, 0.18, 0.12, etc., but are reported arbitrarily as mid-points of those brackets, 1.0, 0.7, 0.5, 0.3, 0.2, 0.15, 0.1, etc. The precision of the spectrographic data is approximately one bracket at 68 percent, or two brackets at 95 percent confidence.)

SAMPLE	ASH %	AL2O3 %	CAO %	FE2O3 %	MGO %	NA2O %	K2O %	SO3 %	SIO2 %	CL %
D169596	16.9	29.	4.1	5.4	2.1	0.22	1.4	5.6	54.	0.10L
D169597	4.9	11.	29.	4.9	3.3	.32	.25	22.	19.	.10L
D169598	14.3	25.	4.7	3.7	1.8	.18	1.6	.62	45.	.10L
D169599	12.2	23.	9.4	6.3	2.1	.18	1.2	4.6	41.	.10L
D169600	17.9	25.	12.	4.3	2.0	.72	1.2	6.5	44.	.10L
D169601	28.3	28.	2.0	4.9	1.8	.49	1.9	3.1	60.	.10L
D169602	18.4	29.	7.2	5.6	1.8	.90	1.3	6.8	46.	.10L
D169603	6.1	13.	30.	7.4	3.8	.84	.36	15.	15.	.10L
D169604	43.0	29.	1.9	3.3	1.4	.59	2.0	1.8	61.	.10L
D169605	25.0	28.	2.2	3.8	1.5	.84	1.9	3.9	58.	.10L
D169606	6.7	10.	26.	10.	3.4	2.5	.29	22.	16.	.10L
D169607	6.6	14.	20.	9.3	3.3	.43	.46	15.	23.	.10L
D169608	16.6	24.	11.	4.2	1.8	.76	1.5	4.1	47.	.10L
D169982	13.4	13.	3.2	40.	1.7	.09	.74	8.0	26.	.10L
D169983	12.5	18.	10.	8.5	6.6	.35	1.0	9.2	44.	.10L

SAMPLE	MNO %	P2O5 %	TIO2 %	CD PPM	CU PPM	LI PPM	PB PPM	ZN PPM	B PPM-S	BA PPM-S
D169596	0.020L	0.10L	0.84	2.	128.	76.	50.	214.	200	2000
D169597	.020L	.10L	.41	1.L	70.	14.	30.	54.	200	5000
D169598	.020L	.54	.67	2.	90.	62.	45.	248.	150	1500
D169599	.055	.53	1.2	2.	148.	52.	35.	127.	300	2000
D169600	.020L	1.1	.75	1.	82.	54.	40.	57.	200	3000
D169601	.020L	.10L	.78	2.	106.	52.	50.	138.	200	1000
D169602	.020L	2.2	.70	2.	100.	110.	50.	165.	200	3000
D169603	.043	.10L	.34	1.L	84.	18.	45.	52.	700	3000
D169604	.020L	.84	.72	1.	96.	156.	50.	226.	100	2000
D169605	.020L	.10L	.68	2.	142.	64.	55.	234.	150	1500
D169606	.087	.10L	.33	1.	86.	10.	35.	72.	500	5000
D169607	.032	.10L	.48	1.	130.	26.	30.	42.	500	3000
D169608	.028	.28	.72	1.L	98.	68.	40.	40.	150	2000
D169982	.41	.76	.47	1.L	60.	46.	25.	146.	300	1500
D169983	.020L	.82	.75	1.L	50.	38.	35.	36.	500	2000

SAMPLE	BE PPM-S	CO PPM-S	CR PPM-S	GE PPM-S	LA PPM-S	MO PPM-S	NB PPM-S	NI PPM-S	SC PPM-S	SR PPM-S
D169596	5	15	150	N	70	10	20	50	20	200
D169597	3	10	30	N	N	7	10 L	30	10	3000
D169598	3	15	100	N	150	10	20	70	20	500
D169599	N	15	70	N	70	10	20	50	20	1500
D169600	3	15	100	N	100	15	10 L	30	20	2000
D169601	7	15	100	N	100	15	20	30	20	300
D169602	7	20	100	N	150	15	10 L	30	20	1500
D169603	7	30	70	N	70	7	N	50	15	1500
D169604	3	10	100	N	100	10	10 L	30	15	1000
D169605	5	15	70	N	100	20	10 L	30	20	500
D169606	7	30	30	20	70	15	10 L	70	15	2000
D169607	7	10	50	N	70	30	N	30	15	2000
D169608	3	10	70	N	70	7	10 L	15	10	2000
D169982	5	15	50	N	N	15	10	70	20	500
D169983	3	20	70	N	N	15	10	20	15	1000

Table 6--Major and minor oxide and trace element composition of the laboratory ash of fifteen samples from the Hanna Basin, Wyoming.--Continued

SAMPLE	V PPM-S	Y PPM-S	YB PPM-S	ZR PPM-S
D169596	200	70	7	150
D169597	70	50	5	70
D169598	200	70	7	100
D169599	150	70	7	150
D169600	200	50	5	150
D169601	200	50	7	150
D169602	200	70	7	150
D169603	150	70	7	70
D169604	200	50	5	150
D169605	200	70	7	150
D169606	150	50	5	100
D169607	150	50	7	150
D169608	150	30	3	150
D169982	200	70	B	30
D169983	200	50	5	50

Table 7.--Content of seven trace elements in fifteen samples from the Hanna Basin, Wyoming. (Analyses on air-dried (32°C.) coal. All values are in parts per million. L after a value means less than the value shown, B means not determined.)

SAMPLE	AS PPM	F PPM	HG PPM	SB PPM	SE PPM	TH PPM	U PPM
D169596	4.	150.	0.14	1.1	1.1	9.1	4.0
D169597	1.	25.	.06	.2	.3	B	.4
D169598	3.	155.	.13	.8	1.9	8.9	4.2
D169599	5.	105.	.10	.6	1.1	5.9	1.8
D169600	4.	115.	.07	.6	.5	7.6	3.7
D169601	35.	285.	.25	1.3	1.3	13.0	5.5
D169602	5.	230.	.25	1.0	1.0	9.7	5.5
D169603	1.	40.	.03	.2	1.1	3.2	.6
D169604	5.	460.	.13	1.5	1.4	15.3	9.1
D169605	10.	225.	.13	2.0	1.3	10.8	9.6
D169606	5.	40.	.12	.8	2.2	2.1	.9
D169607	3.	55.	.09	.7	.5	2.4	1.7
D169608	1.	175.	.05	.6	.7	6.9	2.1
D169982	3.	95.	.07	.7	.5	10.1	.1
D169983	4.	160.	.07	.7	.4	12.8	.2

Table 8.--Major, minor and trace element composition of fifteen samples from the Hanna Basin, Wyoming, reported on whole-coal basis. (Values are in either percent or parts per million. Al, Ca, Fe, Mg, Na, K, Si, Cl, Mn, P, Ti, Cd, Cu, Li, Pb, and Zn values were calculated from analyses of ash. As, F, Hg, Sb, Se, Th and U values are from direct determinations on air dried (32°C.) coal. The remaining analyses were calculated from spectrographic determinations on ash. L after a value means less than the value shown, N means not detected, and B means not determined.)

SAMPLE	AL %	CA %	FE %	MG %	NA %	K %	SI %	CL %	MN PPM	P PPM
D169596	2.6	0.50	0.64	0.210	0.027	0.20	4.3	0.017L	26.L	74.L
D169597	.29	1.0	.17	.098	.012	.010	.44	.005L	6.L	21.L
D169598	1.9	.48	.37	.152	.019	.19	3.00	.014L	22.L	340
D169599	1.5	.82	.54	.151	.016	.13	2.4	.012L	52.	280
D169600	2.4	1.5	.54	.22	.095	.18	3.7	.018L	28.L	850
D169601	4.2	.40	.98	.30	.10	.440	7.9	.028L	44.L	120.L
D169602	2.8	.94	.73	.20	.12	.192	4.0	.018L	38.L	1800
D169603	.42	1.1	.32	.14	.038	.019	.44	.006L	21.	27.L
D169604	6.6	.57	1.0	.374	.19	.71	12.	.043L	67.L	1600
D169605	3.7	.40	.67	.23	.16	.40	6.8	.025L	39.L	110
D169606	.35	1.3	.47	.14	.12	.016	.49	.007L	45.	29.L
D169607	.49	.96	.43	.132	.021	.025	.72	.007L	16.	29.L
D169608	2.1	1.3	.49	.18	.093	.21	3.6	.017L	36.	200
D169962	.92	.30	3.8	.141	.009	.082	1.6	.013L	430.	440
D169963	1.2	.92	.74	.50	.033	.11	2.6	.012L	19.L	450

SAMPLE	TI %	AS PPM	CD PPM	CU PPM	F PPM	HG PPM	LI PPM	PB PPM	SB PPM	SE PPM
D169596	0.085	4.	0.3	21.6	150.	0.14	12.8	8.5	1.1	1.1
D169597	.012	1.	.1L	3.4	25.	.06	.7	1.5	.2	.3
D169598	.058	3.	.3	12.9	155.	.13	8.9	6.4	.8	.9
D169599	.085	5.	.2	18.1	105.	.10	6.3	4.3	.6	1.1
D169600	.081	4.	.2	14.7	115.	.07	9.7	7.2	.6	.5
D169601	.13	35.	.4	30.0	285.	.25	14.7	14.1	1.3	1.3
D169602	.077	5.	.3	18.4	230.	.25	20.2	9.2	1.0	1.0
D169603	.013	1.	.1L	5.1	40.	.03	1.1	2.7	.2	.1
D169604	.19	5.	.4	41.3	460.	.13	67.1	21.5	1.5	1.4
D169605	.102	10.	.5	35.5	225.	.13	16.0	13.8	2.0	1.3
D169606	.013	5.	.1	5.8	40.	.12	.7	2.3	.8	2.2
D169607	.019	3.	.1	8.6	55.	.09	1.7	2.0	.7	.5
D169608	.072	1.	.2L	16.3	175.	.05	11.3	6.6	.6	.7
D169962	.038	3.	.1L	8.0	95.	.07	6.2	3.3	.7	.5
D169963	.056	4.	.1L	6.3	160.	.07	4.8	4.4	.7	.4

SAMPLE	TH PPM	U PPM	ZN PPM	B PPM	BA PPM	BE PPM	CO PPM	CR PPM	GE PPM	LA PPM
D169596	9.1	4.0	36.2	30	300	.7	2	20	N	10
D169597	B	0.4	2.6	10	200	.1	.5	1.5	N	N
D169598	8.9	4.2	35.5	20	200	.5	2	15	N	20
D169599	5.9	1.8	15.5	30	200	N	2	10	N	10
D169600	7.6	3.7	10.2	30	500	.5	3	20	N	15
D169601	13.0	5.5	39.1	70	300	2	5	30	N	30
D169602	9.7	5.5	34.0	30	500	1.5	3	20	N	30
D169603	3.2	0.6	3.2	50	200	.5	2	5	N	5
D169604	15.3	9.1	97.2	50	1000	1.5	5	50	N	50
D169605	10.8	9.6	58.5	30	300	1.5	3	20	N	20
D169606	2.1	0.9	4.8	30	300	.5	2	2	1.5	5
D169607	2.4	1.7	2.8	30	200	.5	.7	3	N	5
D169608	6.9	2.1	6.6	20	300	.5	2	10	N	10
D169962	10.1	0.1	19.6	50	200	.7	2	7	N	N
D169963	12.8	0.2	4.5	70	200	.5	2	10	N	N

Table 8.--Major, minor and trace element composition of fifteen samples from the Hanna Basin, Wyoming, reported on whole-coal basis.--Continued

SAMPLE	MO PPM	NB PPM	NI PPM	SC PPM	SR PPM	V PPM	Y PPM	YB PPM	ZR PPM
D169596	1.5	3	7	3	30	30	10	1	20
D169597	.3	1 L	1	.5	150	3	2	.2	3
D169598	1.5	3	10	3	70	30	10	1	15
D169599	1	2	7	2	200	20	10	1	20
D169600	3	1 L	5	3	300	30	10	1	30
D169601	5	7	7	7	100	70	15	2	50
D169602	3	1 L	7	3	300	30	15	1.5	30
D169603	.5	N	3	1	100	10	5	.5	5
D169604	5	1 L	15	7	500	100	20	2	70
D169605	5	1 L	7	5	150	50	20	2	30
D169606	1	1 L	5	1	150	10	3	.3	7
D169607	2	N	2	1	150	10	3	.5	10
D169608	1	1 L	2	1.5	300	20	5	.5	20
D169982	2	1.5	10	3	70	30	10	B	5
D169983	2	1.5	3	2	150	20	7	.7	7

Table 9.--Locality and other information on coal samples analyzed

Sample number	BLM drill hole number or mine name	Type of sample	Depth of drill hole sample	Formation	Bed number of Dobbins and others (1929)	Location		
						Section	Township north	Range west
D169596	MS-9007	Core	87.0-90.0	Ferris	36	NE 1/4 NE 1/4 6	23	83
D169597	Seminoe #1	Shot pile		Ferris	24	SW 1/4 7	22	83
D169598	Seminoe #2	Shot pile		Hanna	2	SW 1/4 4	22	81
D169599	Rosebud	Tipple		Hanna	82	9	22	81
D169600	MS-9004	Core	115.5-117.4	Ferris		SE 1/4 SE 1/4 6	23	83
D169601	MS-9004	Core	148.1-151.5	Ferris		SE 1/4 SE 1/4 6	23	83
D169602	MS-9004	Core	195.5-200.8	Ferris		SE 1/4 SE 1/4 6	23	83
D169603	MS-9005	Core	39.2-41.2	Ferris		SW 1/4 NE 1/4 12	23	84
D169604	MS-9005	Core	95.5-97.0	Ferris		SW 1/4 NE 1/4 12	23	84
D169605	MS-9005	Core	114.0-115.5	Ferris		SW 1/4 NE 1/4 12	23	84
D169606	MS-9005	Core	159.0-162.1	Ferris		SW 1/4 NE 1/4 12	23	84
D169607	MS-9008	Core	77.3-82.7	Ferris	34	SW 1/4 SW 1/4 12	23	84
D169608	MS-9008	Core	104.9-111.5	Ferris	35	SW 1/4 SW 1/4 12	23	84
D169982	MS-9001	Core	113.0-123.0	Ferris	32	SE 1/4 SE 1/4 30	24	83
D169983	MS-9002	Core	69.3-75.5	Ferris	35	NE 1/4 NE 1/4 32	24	83

Table 10.--Comparison of Hanna Basin coals with coals of the Northern Great Plains

	Hanna Basin coals (15 samples)	Northern Great Plains Subbituminous coals (67 samples)	Northern Great Plains Lignite (62 samples)
Moisture (as rec'd.)[1]	11%	20%	35%
Fixed carbon (as rec'd.)[1]	44%	38%	30%
Oxygen (as rec'd.)[1]	24%	30%	42%
Btu (as rec'd.)[1]	10,390	9,000	6,800
SiO_2 (in ash)	40%	25%	15%
Na_2O (in ash)	0.6%	0.5%	2%
CaO (in ash)	12%	15%	25%
MgO (in ash)	2.6%	4%	8%
As (whole coal)	6 ppm	2 ppm	5 ppm
B (whole coal)	30 ppm	50 ppm	150 ppm
Ba (whole coal)	300 ppm	200 ppm	700 ppm
Hg (whole coal)	0.11 ppm	0.08 ppm	0.13 ppm
Pb (whole coal)	7.2 ppm	6 ppm	3 ppm
U (whole coal)	3.3 ppm	0.7 ppm	1.1 ppm
Zn (whole coal)	24.7 ppm	7 ppm	2 ppm

[1]Only 5-sample analyses.

Table 11.—Elements that can affect potential utilization of coal content in fifteen Hanna Basin coal samples.

Element	Range in parts per million	Average in parts per million	Average continental crust (Clarkes) (Taylor, 1964)
As	1 - 35	6	1.8
Cd[1]	0.1 - 0.5	0.2	0.2
Cu	3.4 - 41.3	16.4	55
F	25 - 460	150	625
Hg	0.03 - 0.25	0.11	.08
Li	0.7 - 67.1	12.1	20
Pb	1.5 - 21.5	7.2	12.5
Sb	0.2 - 2.0	0.9	0.2
Se	0.1 - 2.2	0.9	.05
Th[1]	2.1 - 15.3	8.4[1]	9.6
U	0.1 - 9.6	3.3	2.7
Zn	2.6 - 97.2	24.7	70

[1]Fourteen samples used.

value about 0.9 ppm compared to 0.05 ppm average crustal abundance) has been enriched or depleted in Hanna Basin coals by more than an order of magnitude. The other trace elements are present in amounts that approximate (i.e., same order of magnitude) their abundances in the continental crust.

Soil

General characteristics of soils of the study area

Soils of the study area are primarily of the Aridosol order and the Orthid and Argid suborders. Great soil groups represented in the study area include Torriorthids, Camborthids, Calciorthids, Natrargids, and Haplargids. Inclusions of Mollisols and Inceptisols are found within some of the mapping units, but their areal extent and significance in a revegetation program was considered to be minor and not worthy of the additional time and effort required for separation.

Three principal soil groupings related to the landforms of the study site are observable. These include: (1) The deep soils of the enclosed drainage basins (playa lakes), (2) Moderately deep upland soils occurring along the uplifted geologic formations (gentle ridge slopes), and (3) Severely eroded and shallow soils occurring along deeply incised drainageways and geologic outcrops. The Torriorthids (8001 series) are included in the first group; the Haplargids, Natrargids and Calcirthids (8010 series, 8020 series and 8030 series) in the second group; and the Camborthids and rough Broken Land type (8040 series and 8050 series) in the third group.

The soils of group number one are generally deep, heavy textured and somewhat poorly drained. Permeabilities are generally slow throughout the profile. These soils are not unacceptable from the standpoint of chemical characteristics for the purpose of use as a revegetation material.

The soils of group number two are more variable in their characteristics. Depth of soil material over consolidated bedrock varies from about 10 inches to somewhat over 36 inches, with the deeper soils generally being on the south and east facing slopes and the shallower soils being generally on the north and west facing slopes. Permeabilities of these soils are generally moderately rapid. Chemically, these soils are generally suitable for use as a plant growth medium, with the possible exception of soil series 8020 which shows less than optimum pH, exchangeable sodium and soluble salts values.

Group number three is composed of soils and land types which are generally very shallow over bedrock, contain many rock fragments and/or gravels, and are frequently high in exchangeable sodium and/or soluble salts. Those soils of series number 8040 are generally not chemically deficient, but permeabilities are excessive and water holding capabilities are quite low.

Typical soil profiles

The principal mapping units occurring within the study area are described in detail. These descriptions include Bureau of Land Management forms 7310-9 which are quite detailed in their outline of soil physical properties. The described mapping units have not been correlated into series at this time, and consequently, code numbers are used for their identification rather than series names. Additionally, the legend preceding the descriptions illustrates the symbolization used in field mapping operations and indicates soil factors which were considered to be of primary importance for the purposes of this study.

8001 series, clay, 0 - 3 percent slopes

This is a deep, well-drained clay soil occurring primarily within the southwestern part of the study site. It is developing in fine-textured local alluvium originating in the surrounding shale formations, and occurs within small enclosed drainage basins (playa lakes). There are approximately 69 acres in the study site. Elevation of occurrence of this soil is, as with other soils of the study site, about 6,400 feet. Average annual rainfall is about 12 inches and mean annual temperature is about 43 degrees. Slopes on which this soil occurs are primarily less than 1 percent, and the aspect is flat.

The surface layer is light yellowish-brown, silty clay about 5 inches thick. The underlying C horizons are light yellowish-brown clays averaging over 60 inches in depth.

Permeability of this soil is slow to moderate. Available water holding capacity is very high. Effective rooting depth is 60 inches or more. Surface runoff does not occur, since no drainage outlets exist for these small lakes, and erosion hazard is slight.

These soils show very little variation in characteristics within the study site. The colors apparent for surface soil vary from light grayish-brown to light yellowish-brown, and textures vary from light silty clays to heavy silty clays.

Soil behavior

This soil is presently used for grazing, and is moderately productive of native forage. Since the most pertinent probable use of this soil relates to it's behavior as a plant growth medium under strip-mined conditions, this discussion will primarily deal with that subject. This is the thickest soil of the study area and, for that reason, represents a quantity source of backfill material

to be used as a plant growth medium. Textures are, however, too heavy to be suitable for this purpose. Infiltration rates would be excessively slow, although holding capacity would be high. Compaction of these fine-textured material could be expected to cause a problem.

The above mentioned factors which make this soil (in a disturbed state) a poorly suited material for use as a plant growth medium can be at least partially overcome by mixing with coarser textured materials. Many of the surrounding soils within the study site are overly coarse in texture, and could easily be mixed with this soil material to form a more moderate textured replacement topsoil. A description of a typical profile within this mapping unit follows.

FIELD MAPPING LEGEND

Surface Texture

Subsoil Texture

Substrata

Depth

Sodicity

Salinity

Parent Rock

3 2 3 1 A_x S_x X

B 15

Slope

Erosion Factor

Surface Texture - Subsoil - Substrata

1 - clay
2 - CL, SiCL
3 - SiL, L, FSL, VFSL
4 - LS, LFS
5 - S

SCL → 2 27+% clay
SCL → 3 27-% clay

Erosion

Stable 0-20
Slight 21-40
Moderate 41-60
Critical 61-80
Severe 81-100

Depth

1 - 40+
2 - 20-40"
3 - 10-20"
4 - 0-10"

Slope

A - 0-3%
B - 3-7%
C - 7-12%
D - 12-20%

Parent Rock

X = M - Sandstone
N - Siltstone
C - Shale
C_c - Coal

Special Factors

A - Sodicity
x = 1 - slight
2 - moderate
3 - severe

S - Salinity
x = 1 - slight
2 - moderate
3 - severe

8001 Series

Ustic Torriorthid (Playa)

$\frac{1111\ A_1 S_2 M}{A\text{-}7}$

A 0-5" - Light yellowish brown (2.5y 6/3) silty clay; fine subangular blocky; hard, very firm, clear smooth boundary.

C_1 5-32" - Light yellowish brown (2.5y 6/3) clay; fine subangular blocky; very hard, very firm, few fine roots to 12"; (pH 8.2) clear wavy boundary.

C_2 32-60" - Light olive brown (2.5y 5/3) clay; massive; very hard, very firm, (pH 8.6) clear wavy boundary.

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State	2. District	3. Planning Unit	4. Vegetation–Soil Unit	5. Soil Map Symbol	6. Surname	7. Date
Wyo.	--	--	/	----		9 mo 74 yr

8. Area	9. County	10. Location	11. Photo No.	12. Writeup No.	13. File No.	14. Parent Rock
--	Carbon	Sec. 12, T. 23N, R. 84W	12	----	------	

15. Formation Name	16. Surface Conditions (percent)	17. Land Conditions	18. Landform
	Stone -- Rock --	Alkaline slight Saline mod Water table	Alluvium Playa

19. Slope (percent)	20. Aspect	21. Elevation	22. Present Erosion	23. Hydrologic Group
0-1% [X] Single [ ] Complex	--	-----	Type SSF --- Class –	–

24. Precipitation (in)	25. Temperature	26. Frost-free	27. Drainage Class	28. Infiltration	29. Percolation	30. ERD	31. AWC
– 1st, 2nd, 3rd, 4th	-- Air -- Soil	Days --- > 28°	surface - closed basin			-- in	--.– in

32. HORIZON	33. THICKNESS	34. COLOR Dry	34. COLOR Moist	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY D M Wet	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH)	42. BOUNDARY
A	0-5	2.5Y 6/3	2.5Y 4/3	SiC	1cpl->fine 3 fsabk	dH VFm very sticky	-	com-fine Few med.	0	E_s 8.2	Clear-smooth
C_1	5-32	2.5Y 6/3	2.5Y 4/3		2 fsabk	dVH " "	-	Few -fine to 12"	0	E_s 8.2	Clear-wavy
C_2	32-60	2.5Y 5/3	2.5Y 4/2		massive	" " "	-	-	0	E_v 8.6	Clear-wavy

Sampled 0 - 32"

Samples 32- 60"

$\frac{111\ -1\ A_1 S_2 M}{A\ -}$

C_2 - Many seams and masses of secondary carbonates

Western Wheatgross, Grease wood

65

(Instructions inside back cover)

Form 7310–9a (December 1970)

8010 series, sandy loam, 3 - 12 percent slopes

This is a moderately deep, moderately well-drained sandy to sandy clay loam soil occurring throughout the study site, primarily on the southeast facing slopes of the northeast-southwest facing slopes of the northeast-southwest trending ridges. It is developing in a mixture of fine-textured residual shaley material and coarser textured sandy aeolian material. There are approximately 231 acres in the study site. Elevation of occurrence of this soil is the same as the other soils of the study site (about 6,400 feet). Average annual rainfall is about 12 inches and mean annual temperature is about 43 degrees. Slopes on which this soil occurs vary from 3 to 12 percent and the aspect is primarily southeast.

The surface horizon is a pale brown sandy loam about 2 inches thick. The underlying B2t and B3Ca horizons are a yellowish-brown to pale brown sandy clay loam, about 12 inches in thickness. Below the B horizon, a light brownish-gray substratum of sandy loam texture about 22 inches in thickness is encountered. Below a depth of approximately 36 inches the underlying bedrock material is encountered, this is a pale brown soft calcareous sandstone.

Permeability of this soil is moderate, as is the available water holding capacity. Effective rooting depth is 36 inches or slightly more, since the soft sandstone material encountered below the soil profile is relatively easily penetrable by roots. Surface runoff and erosion hazard would be moderate, since the surface permeability is great enough to allow infiltration of most rainfalls normal to the area. The range of characteristics of this soil includes two mapping units separated on the basis of slope, one unit having 3 to 7 percent slopes comprises about 53 percent of this soil type, while the 7 to 12 percent unit comprises about 47 percent.

Depth to underlying bedrock varies from 30 to 48 inches within this unit, and surface texture may approach a sandy clay loam.

Soil behavior

This soil, like others within the study site, is presently used for grazing and is moderately productive of native forage. Since this study deals with a probable future of strip mining within the area, soil behavior related to its use as a plant growth medium after disturbance of the land is of primary importance.

This soil is relatively thick and represents a good potential source of material for stockpiling and return to the surface at completion of mining operations and prior to reseeding. Use of the 36-inch depth of developed soil and weathered substratum would result in a good quantity of material having relatively

good permeability and water holding capacity. Chemical characteristics of this soil are such that no adverse affects would be expected on plant growth. Erodability from both wind and water could be a problem and procedures (such as mulching) to combat this should be used.

A typical profile description for this mapping unit follows.

FIELD MAPPING LEGEND

Surface Texture

Subsoil Texture

Substrata

Depth

Sodicity

Salinity

Parent Rock

3 2 3 1 A_x S_x X

B 15

Slope

Erosion Factor

Surface Texture - Subsoil - Substrata

1 - clay
2 - CL, SiCL
3 - SiL, L, FSL, VFSL
4 - LS, LFS
5 - S

SCL → 2 27+% clay
SCL → 3 27-% clay

Erosion

Stable 0-20
Slight 21-40
Moderate 41-60
Critical 61-80
Severe 81-100

Depth

1 - 40+
2 - 20-40"
3 - 10-20"
4 - 0-10"

Slope

A - 0-3%
B - 3-7%
C - 7-12%
D - 12-20%

Parent Rock

X = M - Sandstone
N - Siltstone
C - Shale
C_c - Coal

Special Factors

A - Sodicity
x = 1 - slight
2 - moderate
3 - severe

S - Salinity
x = 1 - slight
2 - moderate
3 - severe

8010 Series

Boralic Haplargid

$\frac{3332\ A_1S_1M}{B-29}$	$\frac{3332\ A_1S_1M}{C-39}$

A_2 0-2" - Pale brown (10YR6/3) sandy loam, fine subangular blocky to fine crum; soft, very friable; clear smooth boundary

B_{2t} 2-10" - Yellowish brown (10YR5/4) sandy clay loam, medium prismatic to coarse subangular blocky; hard, friable; clear wavy boundary many fine and few medium roots 0-5"

B_{3Ca} 10-14" - Pale brown (10YR6/3), sandy clay loam, medium prismatic to coarse and medium subangular blocky; hard, friable; gradual wavy boundary, common medium soft round masses and seams of secondary lime present; common fine and medium few roots 5-15"

C_{ca} 14-36" - Light brownish grey (2.5Y6/2) sandy loam; massive; slightly hard, very friable, few fine roots 30"

Cr 36+ - Pale brown calcareous sandstone, soft

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State Wyo	2. District – –	3. Planning Unit – –	4. Vegetation–Soil Unit – – – – – – – – – – – / – – – – – – –	5. Soil Map Symbol – – – –	6. Surname Borollic Haplargid – f_1L_1M – – –	7. Date 9 mo 74 yr
8. Area – –	9. County Carbon	10. Location Sec. 30, T. 83W, R. 24N	11. Photo No. – – – – – – – – – – – –	12. Writeup No. – – – –	13. File No. – – – – – – –	14. Parent Rock
15. Formation Name Ferris	16. Surface Conditions (percent) Stone – – Rock – –	17. Land Conditions Alkaline – Saline – Moisture = Dry Water table –				18. Landform Calcarous sandstone, Ferris Foundation (upland)
19. Slope (percent) 2–3% ☐ Single ☐ Complex	20. Aspect SE –	21. Elevation side slope	22. Present Erosion sl Type SSF – – – Class –			23. Hydrologic Group –
24. Precipitation (in) 10–14" 1st, 2nd, 3rd, 4th	25. Temperature – – Air – – Soil	26. Frost-free Days – – – > 28°	27. Drainage Class well	28. Infiltration	29. Percolation	30. ERD – – in; 31. AWC – – . – in

32. HORIZON	33. THICKNESS	34. COLOR Dry	34. COLOR Moist	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY D – M – Wet	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH)	42. BOUNDARY
A_2	0-2"	Pale brown 10YR 6/3	10YR 5/2	SL 14%	18 sabk-> 18 cr	S Ufri SO_1PO				0	CS
B_{2t}	2-10"	Yellowish brown 10YR 5/4	10YR 4/4	SCL 24%	2 mpr *1 -> 2 csabk	h Fri SP_1				0	CW
B_{3ca} *2	10-14"	Pale brown 10YR 6/3	10YR 5/3	SCL 20%	1 mpr-> 2 c&msabk	" " S_1P				es	GW
C_{ca}	14-36"	2.5Y 7/2	2.5Y 6/2	SL	m	SH Ufri SO_1PO				ev	
Cr	36-40"	Pale brown calcareous sandstone soft									

Typical Series = "B_2t 10" or less (6-10") sandstone (20-40") 18-35" clay"

*1 = Patchy, glossy coatings on faces of peds

*2 = Common medium soft roud masses and seams of secondary lime

Vegetation = Big sage (low); western wheat; P.OA; sedge; needle & thread; few sping hopsage; few shadscale

% Coarser than UFS >35%

Roots = many fine and few medium 0-5", common fine and few medium 5-15", few fine 15-30"

(Instructions inside back cover)

Form 7310–9a (December 1970)

8020 series, sandy loam, 0 - 12 percent slopes

This is a shallow, moderately well-drained sandy loam to sandy clay loam soil occurring throughout the study site, primarily on southeast facing slopes of the northeast-southwest trending ridges. It is developing residually on moderately fine-textured, if somewhat sandy, shales. There are approximately 537 acres in the study site. Elevation of occurrence of this soil is about 6,400 feet. Average annual rainfall is approximately 12 inches and mean annual temperature is about 43 degrees. Slopes on which this soil occurs vary from 0 to 12 percent and the aspect is mainly southeast.

The surface horizon is a light gray to pale brown fine sandy loam about 1½ to 2 inches thick. This horizon shows, in many places, the bleached single grain appearance of an A2 horizon. Immediately below this shallow surface horizon, the dark yellow-brown to light gray B horizon is encountered. The texture of this horizon is a clay loam or sandy clay loam, and the thickness is approximately 14 inches. Underlying the B horizon, a layer of greyish-brown loamy sand substratum material about 12 inches thick is encountered which overlies the greyish-brown fragmented shale bedrock material. Permeability of this soil is moderately rapid, and available water holding capacity is somewhat low. Effective rooting depth is between 24 to 36 inches. Surface runoff and erosion hazard would be moderate since the surface permeability is adequate to prevent excessive runoff during most precipitation events normal to the area. The range of characteristics of this soil includes three mapping units separated on the basis of slope; one unit having 0 to 3 percent slopes, one having 3 to 7 percent slopes, and the third having 7 to 12 percent slopes. The 0 to 3 percent slope unit comprises 22 percent of this soil type, the 3 to 7 percent slope unit comprises 75 percent, and the 7 to 12 percent slope unit comprises 3 percent. Depth to underlying bedrock varies from 24 to 36 inches, and surface textures may be sandy clay loams in areas where the native topsoil has been eroded away.

Soil behavior

Present use of this soil type within the study site is for range, with forage production being poor to moderate. The behavior of this soil related to its use as a source of surface backfill for re-establishment of vegetation subsequent to strip mining operations is of primary importance in this study.

This soil is somewhat shallow and represents a relatively meager source of material for stockpiling and return to the surface at completion of mining operations and prior to reseeding. Use of

the 28-inch depth of developed soil and substratum material would result in a fairly good quantity of backfill material, but indications of exchangeable sodium and salinity problems limit the usefulness of these soil materials as a plant growth medium.

Water holding capacities of these soils are good, for the most part, with the exception of the loamy sand substrata which would be deficient in this area. Permeability of these soils is generally adequate in their present state, but should salinity or sodicity problems become aggrevated upon their disturbance, permeabilities could become slow. Erodability of these soils, when used as a stockpiled source of surface backfill material, is likely to become a problem, particularly with the loamy sand substratum, and those procedures such as mulching should be used to control such effects.

A typical soil profile description for this mapping unit follows.

FIELD MAPPING LEGEND

Surface Texture
Subsoil Texture
Substrata
Depth
Sodicity
Salinity
Parent Rock

$$\frac{3\quad 2\quad 3\quad 1\qquad A_x\quad S_x\qquad X}{B\qquad\qquad 15}$$

Slope
Erosion Factor

Surface Texture - Subsoil - Substrata

1 - clay
2 - CL, SiCL
3 - SiL, L, FSL, VFSL
4 - LS, LFS
5 - S

SCL → 2 27+% clay
SCL → 3 27-% clay

Erosion

Stable 0-20
Slight 21-40
Moderate 41-60
Critical 61-80
Severe 81-100

Depth

1 - 40+
2 - 20-40"
3 - 10-20"
4 - 0-10"

Slope

A - 0-3%
B - 3-7%
C - 7-12%
D - 12-20%

Parent Rock

X = M - Sandstone
N - Siltstone
C - Shale
C_c - Coal

Special Factors

A - Sodicity
x = 1 - slight
2 - moderate
3 - severe

S - Salinity
x = 1 - slight
2 - moderate
3 - severe

8020 Series

Boralic Natrargid

$\frac{3232 - A_2S_1C}{A\text{-}25}$ X $\frac{3232 - A_2S_1C}{B\text{-}36}$ X $\frac{3232 - A_2S_1C}{C\text{-}45}$

A_1 0-1½" - Light gray (2.5Y 7/2) fine sandy loam, fine to medium subangular blocky, soft, friable, common fine and medium roots, 0 percent coarse fragments, abrupt smooth boundary.

A_2 1½-2" - Pale brown (10YR6/3) sandy loam, medium granular, soft, friable, clear smooth boundary.

B_{21} 2-4" - Dark yellow brown (10YR4/4) clay loam, medium to coarse angular blocky, hard, friable, slightly plastic, gradual smooth boundary.

B_{22} 4-11" - Brown (10YR5/3) sandy clay loam, medium coarse to fine subangular blocky, hard, firm, slightly plastic, gradual wavy boundary.

B_{3Ca} 11-16" - Light gray (10YR7/1) clay loam, medium fine to angular blocky, hard, firm, gradual wavy boundary (High pH)

C 16-28" - Greyish brown (10YR5/4) loamy sand, granular, soft, loose, gradual smooth boundary (High pH)

R 28+" - Greyish brown (10YR5/4) fragmented shale chips

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION—SOIL DESCRIPTION

1. State Wyo. | 2. District — | 3. Planning Unit — | 4. Vegetation—Soil Unit — / — | 5. Soil Map Symbol I | 6. Surname — | 7. Date 7/31/74 (mo – yr)

8. Area — | 9. County Carbon | 10. Location 500 NW of S¼ Cor Sec. 32, T. 24N, R. 83W | 11. Photo No. — | 12. Writeup No. — | 13. File No. — | 14. Parent Rock

15. Formation Name Ferris | 16. Surface Conditions *(percent)* few small sandstone frags Stone 0 Rock — | 17. Land Conditions: Alkaline High pH in B_3ca and C Saline; Water table No | 18. Landform Residium or Ferris Sandy Shale (upland)

19. Slope *(percent)* 4-6% gently undulating [x] Single [ ] Complex | 20. Aspect SE | 21. Elevation 6500' | 22. Present Erosion Type; SSF — Class — | 23. Hydrologic Group —

24. Precipitation *(in)* 10-14 <47°F; >59°F — 1st, 2nd, 3rd, 4th | 25. Temperature — Air — Soil | 26. Frost-free Days — > 28° | 27. Drainage Class well, ground H_2O deep; moisture dry | 28. Infiltration MS | 29. Percolation | 30. ERD — in | 31. AWC — in

75

32. HORIZON	33. THICKNESS	34. COLOR DRY / MOIST — MATRIX	MOTTLING	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY DRY MOIST most important	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH)	42. BOUNDARY
A_1	0-1½"	2.5Y 7/2Lt.Gray 10Yr 5/2Gr.Br.		FSL	2mpl	D-Soft M-Friable	-	Few	-		Abrupt smooth
A_2	1½"-2"	10Yr 6/3Pale Br. 10Yr 5/2Gr.Br.		SL	2mgr	D-Soft M-Friable	-	Few	-		Clear smooth
B_{21}	2"-4"	10Yr 4/4Dk.Y.Br. 10Yr		CL	2mc to 3mabk	D-Hard M-Sl. Firm	Continuous thick	Few	-		Gradual smooth
B_{22}	4"-11"	10Yr 5/4 3Y.Br. 10Yr 5/3 Br.		SCL	2mc to 3fsbk	D-Hard M-Sl. Firm	Continuous thick	Few			Gradual wavy
B_3ca	11-16"	10Yr 7/1Lt.Gr. 10Yr 6/2Lt.Br.	10xR5/4 Y.Br. 10xR5/3 Br.	CL	2msbk to 3fabk	D-Sl. Hard M-Sl. Firm		None			Gradual wavy
C	16-28"	10Yr 5/2 Y.Br. 10Yr 5/4Gr.Br.		LS	0Sgr.	D-Soft M-Loose		None			Gradual smooth
R	28-50"	2.5Y 3/2V Bk Gr. Br.		Fragmented Shale chips		D-Sl. Hard M-Firm					Broken wavy

N. Veg = Birds-foot sage; Nutall saltbush

(Instructions inside back cover)

Form 7310–9a (December 1970)

8030 series, sandy loam, 3 - 20 percent slopes

This is a very shallow, poorly drained sandy loam soil occurring in relatively small scattered areas throughout the study site. It is developing residually in fine-textured sandstones and sandy shales, and occurs primarily on north and west facing slopes where the forces of wind erosion have apparently either prevented deep soil development or removed sufficient material to obliterate soil development. There are approximately 1,200 acres in the study site. Elevation of occurrence of this soil is approximately 6,400 feet and average annual rainfall is about 12 inches. Mean annual temperature is about 43 degrees. Slopes on which this soil occurs vary from 3 to 20 percent, and the aspect is commonly northwest.

The surface horizon is a light brownish-gray sandy loam about 4 inches in thickness. Underlying this material, about 6 inches of highly calcareous substratum material of a loam texture is found. Below a depth of about 10 inches, the calcareous fine-grained sandstone and shale bedrock material is encountered.

Permeability of this soil is rapid, but since it is so shallow to relatively impervious bedrock, its overall in-place permeability would be deficient. Permeability of the backfill material resulting from removal of the top 10 inches of material would be rapid. Effective rooting depth under undisturbed conditions would be less than a foot. Surface runoff would be slight, but erosion, both wind and water hazard, could be somewhat excessive, particularly on the steeper slopes.

The range of characteristics of this soil includes three mapping units separated on the basis of slope; one unit having 3 to 7 percent slopes comprises about 40 percent of this soil type, the second unit having 7 to 12 percent slopes comprises about 48 percent of this soil type, and the third unit having 12 to 20 percent slopes comprises about 12 percent of this soil type. Depth to bedrock varies from about 6 inches to about 16 inches, and surface textures may approach sandy clay loams.

Soil behavior

This soil is presently used for grazing and produces only small quantities of forage. Since this study deals with a probable future of strip mine development, soil behavior related to use as a plant growth medium after disturbance is of primary importance. The shallowness of these soils does not make them a good source of material for use as a plant growth medium. The soil material available from the top 10 inches of this soil would be suitable for plant growth, having a moderate water holding capacity, rapid permeability, and suitable chemical characteristics. Erodability

from both wind and water could be expected to be a problem with this material, and mulching would be necessary after seeding to prevent this. A typical soil profile description for this mapping unit follows.

FIELD MAPPING LEGEND

Surface Texture

Subsoil Texture

Substrata

Depth

Sodicity

Salinity

Parent Rock

$$\frac{3\quad 2\quad 3\quad 1\qquad A_x\quad S_x\qquad X}{B\qquad\qquad 15}$$

Slope

Erosion Factor

Surface Texture - Subsoil - Substrata

1 - clay
2 - CL, SiCL
3 - SiL, L, FSL, VFSL
4 - LS, LFS
5 - S

SCL — 2 27+% clay
SCL — 3 27-% clay

Erosion

Stable 0-20
Slight 21-40
Moderate 41-60
Critical 61-80
Severe 81-100

Depth

1 - 40+
2 - 20-40"
3 - 10-20"
4 - 0-10"

Slope

A - 0-3%
B - 3-7%
C - 7-12%
D - 12-20%

Parent Rock

X = M - Sandstone
N - Siltstone
C - Shale
C_c - Coal

Special Factors

A - Sodicity
x = 1 - slight
2 - moderate
3 - severe

S - Salinity
x = 1 - slight
2 - moderate
3 - severe

8030 Series

Borollic lithic Calciorthid

$\frac{3334\ A_1S_1M}{B-40}$	$\frac{3334\ A_1S_1M}{C-51}$	$\frac{3334\ A_1S_1M}{D-61}$

A_1 0-4" - Light brownish gray (10YR6/2) sandy loam, fine subangular blocky to fine crumb; soft, very friable, 1" vesicular structure (pH 8.2).

C 4-10" - White (10YR8/2) loam, 15 percent fine sandstone channers; soft, very friable (pH 8.6) strong Ca horizon with lime fairly well disseminated

Cr 10"+ Calcareous sandstone bordering on Lithic

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VEGETATION–SOIL DESCRIPTION

1. State	2. District	3. Planning Unit	4. Vegetation–Soil Unit	5. Soil Map Symbol	6. Surname	7. Date
Wyo.	– –	– –	– – – – – – – – – – – / – – – – – – – –	– – – –	L$_1$M.(C) f - Sh Ustic Torriorthents	9 – mo 74 – yr

8. Area	9. County	10. Location	11. Photo No.	12. Writeup No.	13. File No.	14. Parent Rock
– –	Carbon	Sec. – 6 –, T. 83W, R. 23N	– – – – – – – – – – –	– – – –	– – – – – –	

15. Formation Name	16. Surface Conditions (percent)	17. Land Conditions	18. Landform
Ferris	Stone – – Rock – –	Alkaline None Saline None Water table	Residium from calcarous sandstone (Ridge-crest)

19. Slope (percent)	20. Aspect	21. Elevation	22. Present Erosion	23. Hydrologic Group
2-3% ☐ Single ☐ Complex	W	– – – – –	SL Type SSF – – – Class –	–

24. Precipitation (in)	25. Temperature	26. Frost-free	27. Drainage Class	28. Infiltration	29. Percolation	30. ERD	31. AWC
10-14" <47°F; >59° F 1st, 2nd, 3rd, 4th	– – Air – – Soil	Days – – – > 28°		Mod rapid		– – in	– –. – in

32. HORIZON	33. THICKNESS	34. COLOR Dry	34. COLOR Moist	35. TEXTURE	36. STRUCTURE	37. CONSISTENCY D– M– Wet	38. CLAY FILMS	39. ROOTS	40. STONES % VOL.	41. REACTION (pH)	42. BOUNDARY
A$_1$	0-4"	Light brownish gray 10Yr 6/2	10YR 5/2	SL	1 fsack-> 1 fcr *1	S Ufri SO$_1$	PO			e 8.2	cw
C *2	4-10"	10YR 8/2	10YR 7/2	L *3		S Ufri SS$_1$	Ps			ev 8.6	
Cr	10" +	Calcareous sandstone bordering on the lithic									

*1 - 1" vesicular structure

*2 Strong Ca horizon with lime fairly well disseminated

*3 15% fine sandstone channers

Vegetation = W. wheat, big sage; low rabbit brush, shadscale; spring hopsage POA; needle & thread; sedge

% clay = <18%

% coarser than V.F.S. >35%

Roots = common fine 0-4"; few fine > 4"

(Instructions inside back cover)

Form 7310–9a (December 1970)

8040 series, gravelly loam, 0 - 12 percent slopes

This soil is a deep, excessively well-drained, gravelly loam soil occurring in one location: the northwest quarter of section 12 (in the southwest portion of the study site). It is developing in gravelly and cobbly material which is a local alluvium originating in some of the coarser-textured bedrock formations. This material is mixed with sandy aeolian materials. Slopes on which this soil is found vary from 0 to 12 percent, with the aspect being generally to the west. There are approximately 35 acres in the study site. Elevation of occurrence of this soil is approximately 6,400 feet. Average annual rainfall is about 12 inches, and mean annual temperature is about 43 degrees.

The surface horizon is a light brownish-gray gravelly loam of about 3 inches in thickness. Underlying the surface horizon, a layer of cobbly loam material of a light brownish-gray color and about 5 inches in thickness is encountered. Below a depth of about 8 inches, a light gray gravelly loam substratum material is encountered which overlies sandstone and shale bedrock material at a depth of about 40 inches.

Permeability of this soil is extremely rapid, and water holding capacity is low. Effective rooting depth is about 40 inches. Surface runoff is very slight due to the high infiltration rate of the soil, and the hazard of water erosion is slight. Wind erosion hazard is, however, quite high.

The range of characteristics of this soil is primarily in the slopes on which it is found. Two mapping units are delineated; one having 0 to 3 percent slopes and comprising about 56 percent of the soil type and the other having 7 to 12 percent slopes and comprising about 44 percent of this type. Depth to bedrock material varies from about 36 to 44 inches within this soil type.

Soil behavior

This soil is presently used for grazing and produces moderate to small amounts of forage. Soil behavior when disturbed and used for plant growth medium subsequent to strip mining operations is of primary importance in this study, and is discussed below. The coarseness of texture of these soils, and the resultant low water holding capacity, make them relatively unsuitable for use as a source of surface backfill material subsequent to mining operations. Chemical characteristics of these soils are good, and the possibility exists of utilizing this material to mix with heavier textured material from other soil types to form a suitable plant growth medium.

A typical soil profile description for this mapping unit follows.

8040 Series

Borollic Camborthid Gravel

$$\frac{{}^{3}_{G}{}^{3}_{G}{}^{3}_{G}{}^{1}\ A_{1}S_{1}R}{\text{A-17}} \qquad \frac{{}^{3}_{G}{}^{3}_{G}{}^{3}_{G}{}^{1}\ A_{1}S_{1}R}{\text{C-29}}$$

A_1 0-3" - Light brownish gray (10YR6/2) gravelly loam; fine granular; soft, very friable, (pH 8.2), clear smooth boundary

B_2 3-8" - Light brownish gray (10YR4/3) cobbly loam, medium subangular blocky; calcareous, (pH 8.2) clear smooth boundary

C_{1ca} 8-40" - Light gray (10YR7/2) gravelly loam, massive; hard, friable, strongly calarous gradual wavy boundary

8050 (land type), rough broken and stoney land

This mapping unit is a land type composed of about 40 percent rock outcrops, 40 percent severely eroded drainageways and stream channels and 20 percent very shallow lithosols. There are approximately 328 acres in the study site. Elevation of occurrence is about 6,400 feet. Average annual rainfall is about 12 inches, and mean annual temperature is about 43 degrees. Slopes found within this land type vary from almost level to nearly vertical, with the majority being in excess of 20 percent.

The soils within this land type are predominently very shallow (less than 6 inches in depth) or nonexistent. Rock fragments and/or partially decomposed sandstones and shales abound. Chemical properties of these materials are often adverse, with high exchangeable sodium percentages and/or high salinity levels being common. Permeabilities within this land type are often very slow, and water holding capacities almost nil. Surface runoff is great within this land type, and erosion hazard is very high.

Soil behavior

The present use of this land type is for grazing, with forage production generally being very low. Regarding the suitability of this land type as a source of plant-growing material after strip mine disturbance; it would be a very poor choice for the reason outlined above. A typical soil profile description for this mapping unit follows.

8050 Series

(Land Type)

Rough Broken and Stony Land

Consists of very steep land broken by numerous intermittent drainage channels. Contains rock outcrops, eroded areas and very shallow lithosols.

Within the study area, this land type is composed of approximately 40% rock outcrops, 40% severely eroded drainageways and stream channels and 20% very shallow lithosols.

Exhibits 1, 2, 3, 4, and 5, show delineations of mapping units within the various tracts comprising the study area. These maps are tracings taken from the original color infrared aerial photographs with which the initial soil inventory was made.

Table 12 compiles the various delineated mapping units by Section, Township North and Range West in acres and gives the total acreage and percent of each mapping unit in the study area.

Table 12

	Section - Township North - Range West						
Series	12-23-84	6-23-83	32-24-83	36-24-84	30-24-83	Total Acres	Percent In Study Area
(8001)	69.5	0	0	0	0	69.5	2.9
(8010)	80.1	20.5	75.5	11.6	42.9	230.6	9.6
(8020)	162.2	238.3	127.2	0	9.1	536.8	22.4
(8030)	293.4	342.9	329.2	79.7	154.5	1199.7	49.9
(8040)	34.8	0	0	0	0	34.8	1.5
(8050)	0	38.3	108.1	68.7	113.5	328.6	13.7
Total Acres	640.0	640.0	640.0	160.0	320.0	2400.0	100%

The following soil inventory map plate 3 indicates the total area mapped.

Base from U.S. Geological Survey
Pat's Bottom and Seminoe Dam SE
$7\frac{1}{2}$ minute quadrangles

SCALE 1:24,000

1 ½ 0 1 MILE

1 .5 0 1 KILOMETER

MAPPING UNIT

8001
8010
8020
8030
8040
8050

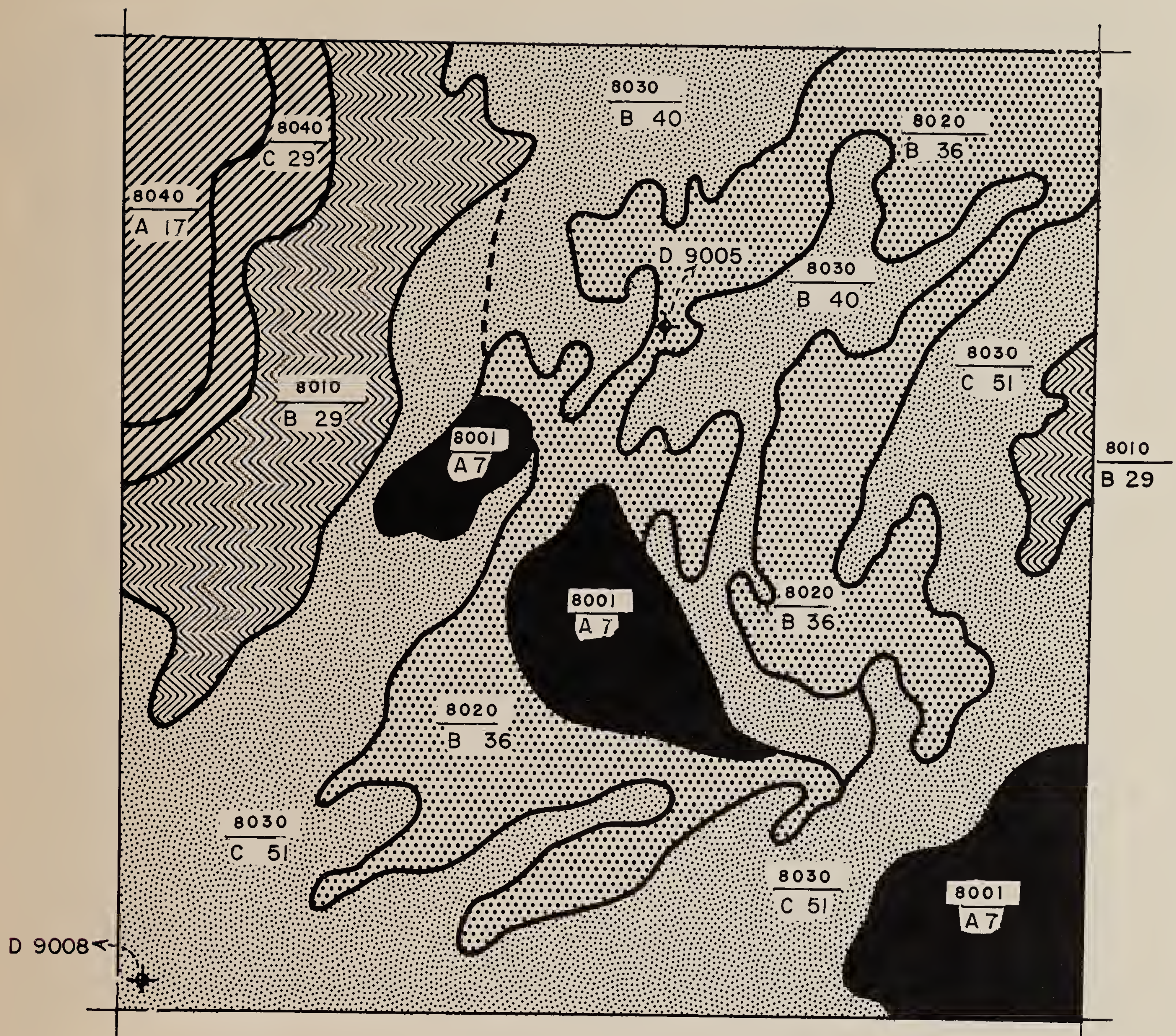
UNITED STATES
DEPARTMENT OF THE INTERIOR

EMRIA HANNA BASIN, WYOMING

SOIL SURVEY MAP

Plate 3

EXHIBIT I

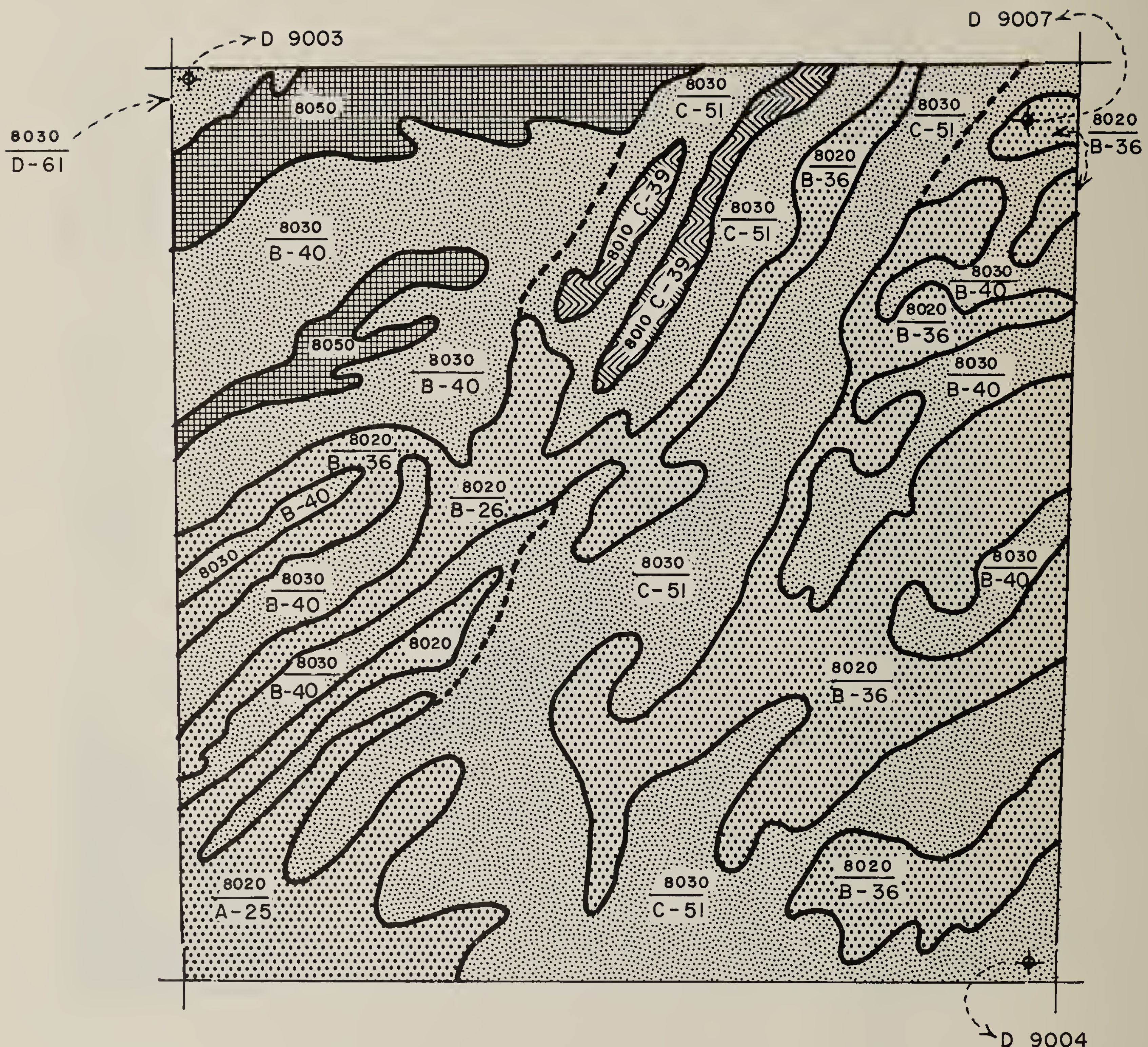


Section 12

Scale 1 : 12,000

1000 0 1000 FT.

EXHIBIT 2

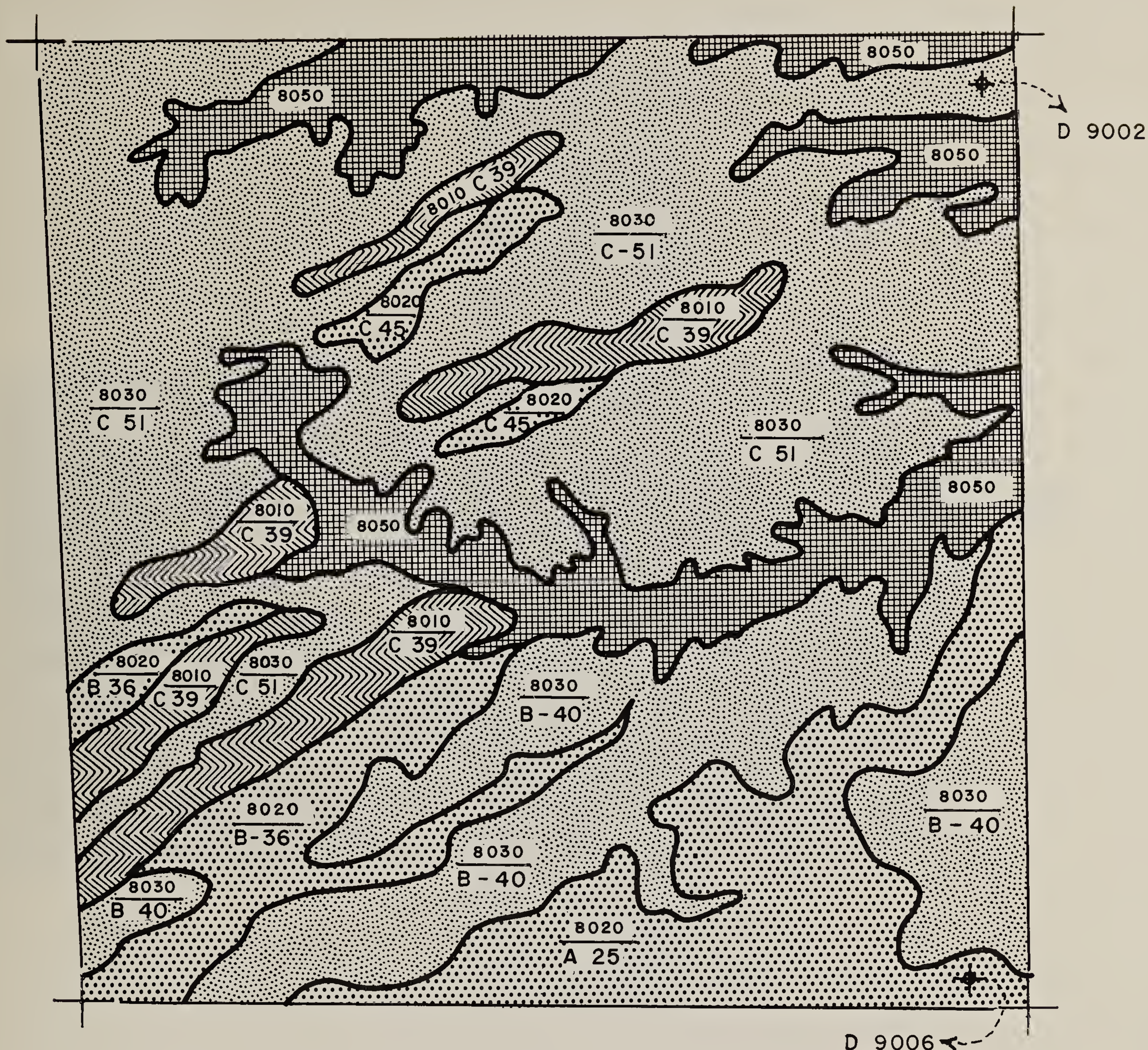


Section 6

Scale 1:12,000

1000 0 1000 FT.

EXHIBIT 3

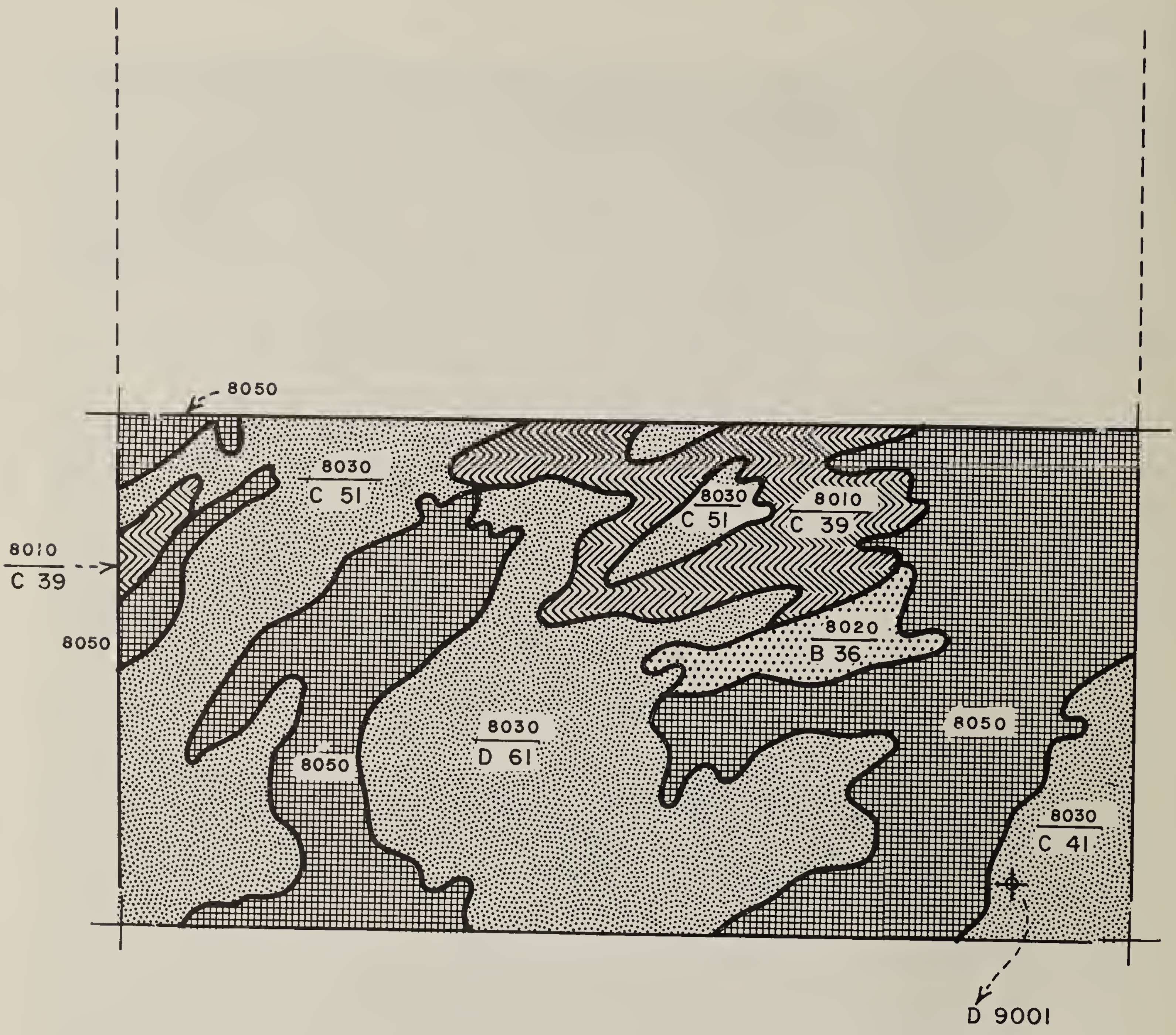


Section 32

Scale 1:12,000

1000 0 1000 FT.

EXHIBIT 4

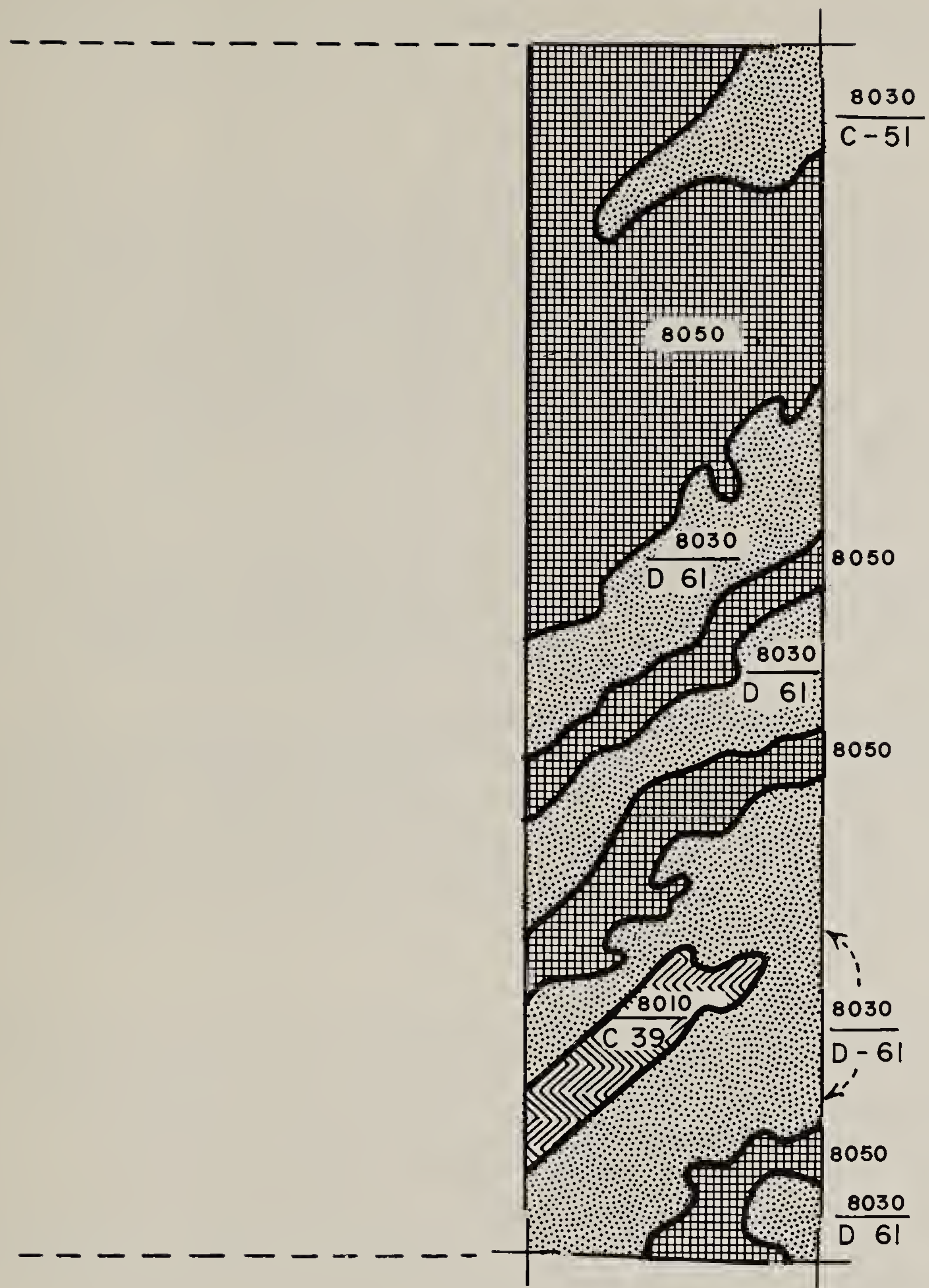


Section 30

Scale 1 : 12,000

1000 0 1000 FT.

EXHIBIT 5



Section 36

Scale 1 : 12,000

1000 0 1000 FT.

Natural soil bodies and their relationship to revegetation

Soil formation processes within the boundaries of the study area have been relatively slow due to the low moisture regime within this part of Wyoming. Consequently, soil development within the area is shallow.

Parent materials consist mainly of sandstones and shales of the Ferris, Medicine Bow, and Hanna formations as well as varying depths of aeolian sands and silts which have been deposited over the area by the historically rather intense prevailing westerly winds. In addition to the above, there are two playa lakes (or enclosed basins) within the study area in which soil parent materials are primarily local alluvium from shales or fine-textured siltstones.

The soils which are forming residually in the sandstones and shales are predominantly shallow (less than 2 feet to parent material), and not very well developed. They range in texture from fine sandy loams to clay loams and are generally light in color with a minimum of organic matter present below the top 2 inches. The soils which are forming in the aeolian materials mentioned above are somewhat deeper (particularly on the leeward side of sandstone and shale ridges), and may be as much as 40 inches over bedrock. These soils show minimum development, range in texture from loamy sands to fine sandy loams, are also light in color and contain minimum amounts of organic matter.

The soils of the playa lakes are deeper (ranging up to 4 or 5 feet in depth) than those previously described owing to the increased deposition of soil material and percolation of water through the soil profile caused by collection of surface water from the surrounding hills. Even with this stepped-up moisture regime, these soils show only moderate development. They range in texture from silty clays to clays, are moderately light in color, somewhat poorly drained, and moderately low in organic matter. Some of these soils are affected to varying degrees by salinity and/or sodicity. As can be seen, the soils of the study area are not ideally suited to revegetation once they have been disturbed. Shallow soil profiles with very thin surface horizons are difficult to stockpile for soil materials and then later distribute it over the reshaped spoil. The quantity of highly suitable soil material for revegetation purposes will be minimal. As a consequence, the possibility of using disturbed overburden material occurring below the soil profile as a medium for plant growth was explored in some detail in this study, and analyses of this material are presented later along with similar analyses of the naturally occurring soils. Insofar as the relationships between the natural soil bodies described above and actual techniques of revegetation are concerned, certain basic facts become apparent. Foremost among these is the

fact that the top soils of the area are relatively shallow and not particularly well developed; consequently, they and the existent plant population are part of a rather fragile ecosystem which will not easily be restored once it is altered in a major way. When examining the problem of revegetation and reclamation of strip mined areas, it is relatively unrealistic to emphasize structure, undisturbed permeability, mottling and other developmental characteristics of these soils when, in all probability, they will be destroyed or obliterated by mining operations. Significant soil characteristics to be considered when soils will be removed, stockpiled, and used for backfill would be such factors as organic matter content, swelling, moisture transmission, chemical status, presence of toxic elements, and texture. Additionally the identification and analysis of soils (as they are commonly defined) may not be nearly as significant as the analysis of the deeper lying overburden materials which are very likely to be utilized as surface backfill material. This is particularly true in the study area, since the shallowness of the soils present would lead to an insufficiency of soil materials to form an adequately deep backfill for a plant growth medium.

Following are completed Bureau of Land Management form 7310-21 through 7310-23 (tables 13, 14, 15, and 16) which evaluate the principal mapping units in terms of physical and chemical properties, possible suitable uses, and management alternatives.

Table 13

INTERPRETIVE RATINGS FOR SELECTED SOIL PROPERTIES AND QUALITIES

MAP SYMBOL	SOIL NAME	CLASS				LIMITING LAYER		EFFECTIVE ROOTING DEPTH (in.)	AVAILABLE WATER CAPACITY (in.)	PRECIPITATION (in.)		EROSION		COMPACTION HAZARD (Class)	FREQUENCY OF FLOODING	REACTION RANGE (pH)	FROST SUSCEPTIBILITY (Class)
		DEPTH	PERMEABILITY	RUNOFF	DRAINAGE	KIND	THICKNESS (in.)			ANNUAL	EFFECT	CONDITION	SUSCEPTIBILITY (Class)				
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
$1111A_1S_2M$ / A-7	Unnamed 8001	VD	Slow	Pond	POD	CP		5	greater than 12	12.1			Stable	Mod	Seal	7.8-8.0	Mod
$3332A_1S_1M$ / A-29, C-39	Unnamed 8010	MD	Mod	Slow	SED	CA		36	4.4	12.1			Slight	Slight	None	8.0-8.4	Mod
$3232A_2S_1C$ / A-25, B-36	Unnamed 8020	S	Mod	Slow	SED	CA		20	6.1	12.1			Slight	Slight	None	8.3-8.8	Mod
$3334A_1S_1M$ / B-40, C-51, D-61	Unnamed 8030	VS	Mod	Slow	WED	CA		10	2.2	12.1			Slight to Moderate	Slight	None	7.5-7.9	Mod
$3_G3_G3_G1A_1S_1R$ / A-17, C-29	Unnamed 8040	VD	VRAP	V Slow	EXD	-	-	6	Less than 3	12.1			Stable to Slight	Slight	None	7.4-8.2	Slight

Table 14

ENGINEERING PROPERTIES OF SOILS

MEASUREMENTS AND INTERPRETATIONS

MAP SYMBOL	SOIL NAME	DEPTH FROM SURFACE OF TYPICAL PROFILE *(inches)*	DEPTH TO		HYDRO-LOGIC SOIL GROUP	SHRINK-SWELL POTEN-TIAL	CORROSIVITY	
			BED-ROCK	SEASONAL HIGH WATER TABLE (inches)			UNCOATED STEEL	CON-CRETE
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$1111A_1S_2M$ / A-7	Unnamed 8001	0-32	60"	Flood Plain	D	Mod	High	High
"	"	32-60	60"	Flood Plain	D	Mod	High	High
$3332A_1S_1M$ / B-29, C-39	Unnamed 8010	2-14	20-40"	60	B	V Low	Low	Low
"	"	14-36	20-40"	60	B	V Low	Low	Low
$3232A_2S_1C$ / A-25, B-36	Unnamed 8020	2-10	10-20"	60	D	Low	Low	Low
"	"	10-20	10-20"	60	D	Low	Low	Low
$3334A_1S_1M$ / B-40, C-51, D-61	Unnamed 8030	0-4	10"	60	D	Low	Low	Low
"	"	4-10	10"	60	D	V Low	Low	Low
$3_G3_G3_G1A_1S_1R$ / A-17, C-29	Unnamed 8040	0-8	40-60"	60	A	V Low	Low	Low
"	"	8-40	40-60"	60	A	V Low	Low	Low

Table 15

INTERPRETIVE RATINGS FOR SOIL USES

MAP SYMBOL (1)	SOIL NAME (2)	SUITABILITY: DRYLAND FARMING (3)	IRRIGATION (4)	TOPSOIL (5)	SAND/GRAVEL (6)	ROAD FILL (7)	OTHER (8)
$1111A_1S_2M$ / A-7	Unnamed 8001	Poor; heavy text., climate	Poor; heavy text., poor drainage	See ratings later in report	Poor; clay texture	Poor to fair clays	Mineral exploration, fair; perm. clay
$3332A_1S_1M$ / B-29, C-39	Unnamed 8010	Fair; climate	Fair; depth	"	Poor; texture	Good	Mineral exploration, fair; water-holding capacity
$3232A_2S_1C$ / A-23, B-36, C-42	Unnamed 8020	Poor; shallow, climate	Poor; shallow, water-holding capacity	"	Poor to fair; texture	Good	Mineral exploration, poor to fair; water-holding capacity
$3334A_1S_1M$ / B-40, C-51, D-61	Unnamed 8030	Poor; shallow, climate	Poor; shallow, water-holding capacity	"	Poor to fair; texture	Fair	Mineral exploration; poor; water-holding capacity
$3_G3_G3_G1A_1S_1R$ / A-17, C-29	Unnamed 8040	Poor; texture, shallow, climate	Poor; texture, shallow, climate	"	Good	Good to fair	Mineral exploration, poor; water-holding capacity

Table 16

DEGREE OF LIMITATION AND SOIL FEATURES AFFECTING														
PONDS					AREAS									
LOCATION	EMBANKMENT	ROAD LOCATION	SHALLOW EXCAVATIONS	BUILDING SITES	CAMP	PICNIC	PLAY	PATHS/ TRAILS	SEPTIC TANK ABSORPTION	SEWAGE LAGOONS	SANITARY LANDFILL (trench)	LAWNS AND GOLF FAIRWAYS	LANDSCAPE PLANTINGS	
(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	
Slight to Moderate	Slight to Moderate	Severe (Drainage)	Moderate (Texture)	Severe (Drainage)	Severe; Poorly Drained; slowly permeable				Severe (Texture)	Moderate to Severe	Severe (Drainage)	-	-	8001
Moderate (Texture)	Moderate (Texture)	Slight	Moderate (Texture)	Slight	Slight to Moderate				Moderate (Depth)	Moderate (Depth and Texture)	Severe (Depth)	-	-	8010
Severe (40" to Bedrock)	Moderate (Texture)	Moderate to Severe (Depth)	Severe (Depth)	Severe (Depth)	Slight to Moderate				Severe (Depth)	Severe (Depth)	Severe (Depth)	-	-	8020
Severe (40" to Bedrock)	Moderate (Texture)	Severe (Depth)	Severe (Depth)	Severe (Depth)	Moderate to Severe (Depth)				Severe (Depth)	Severe (Depth)	Severe (Depth)	-	-	8030
Severe (Permeability	Severe (Permeability	Moderate to Slight	Severe (Texture)	Moderate to Severe	Slight to Moderate				Slight	Severe (Permeability)	Slight	-	-	8040

Greenhouse studies

Greenhouse studies provide for the further means of checking potentials of the materials as a plant growth medium. Representative samples of site soils and overburden materials were sent to Colorado State University for greenhouse studies. Some of the samples were consolidated on the basis of similarities in geologic texture, pH, and electrical conductivities (1:5), to obtain soil volume for duplicate growth testing.

Western wheat grass was used as the test species. The first set was seeded on October 5, 1974, and harvested November 27, 1974. The second set was seeded on January 26, 1975, and harvested March 14, 1975. Each pot was fertilized with 100ppm nitrogen and 80ppm phosphorus. Deionized water was added daily to bring the pots to field capacity.

Large differences in western wheatgrass growth was evident. The samples which produced the least were generally strongly acid (pH less than 5.5). Some yields were high but in evaluating this data it seems that high yields were related to the water added under ideal greenhouse conditions. It is doubtful that these growth tests alone would be a sufficient basis for conclusions, but they provide a worthwhile means of confirming or refuting conclusions reached on the basis of singular analysis.

Weathering data

Laboratory weathering tests involving both freeze-thaw and wet-dry tests were conducted on seven representative core samples (Applied Sciences Referral Memorandum Number 75-1-2). Results of the weathering tests indicated that, in general, the freezing-thawing condition caused more weathering or breakdown than wetting-drying. Although no attempt was made in this study to correlate the laboratory weathering to field weathering, it can be expected that freezing-thawing would also be the most severe of the two conditions in the field. However, the degree of severity would be dependent upon the amount of moisture available at the site, especially during snowmelt and runoff when freezing-thawing might occur.

Chemical and physical laboratory results

Results of laboratory analysis of soil survey samples are presented in table 17. This form was used in place of Bureau of Land Management forms 7310-19 and 7310-20.

Results of laboratory analysis of all overburden materials are presented in table 18. The site number (example D-9001) relates to the geologic drill site location (example MS-9001).

Table 17
SOIL SURVEY
LABORATORY RESULTS

Lab Number	Site Number	Depth Inches	Hydraulic Conductivity Ins./hr. 6th Hr.	Hydraulic Conductivity Ins./hr. 24th Hr.	pH 1:5	pH $CaCl_2$ .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	1:5 Extract ecx10^3 @ 25 c	1:5 Extract Ca+Mg Me/L	1:5 Extract SAR Est.	1:5 Extract Ca+Mg Me/100g	Saturation Extract ecx10^3 @ 25 c	Saturation Extract Na Me/L	Saturation Extract Ca+Mg Me/L	Saturation Extract SAR True	Saturation Extract SAR Est.	Saturation Extract Sat. %	Saturation Extract Ca+Mg Me/100g	Gyp. Me 100g	Na Me/100g Exch. Na	Na Me/100g Cation Exchange Capacity	ESP %	% of Moisture Atmosphere 1/3	% of Moisture Atmosphere 15
	8020																									
1	S32-1-1-74	0-18			8.3			2		.12				.73	6.6	1.0	9.3		33.0	0.03		.78	17.8	4.3	15.3	6.6
2	S32-1-2	18-36			8.5			3		.55				3.42	28.9	9.0	14.0		62.9	0.57		2.78	42.4	6.5	31.5	15.0
	Control																									
3	S32-1-3-74	0-36			8.8			2		.08				.69	6.0	2.0	6.3		28.6	0.06		.63	14.6	4.3	13.4	5.9
	8030																									
4	S-32-2-1-74	0-2			7.9			1		.04				.61	.36	7.0	.2		33.1	0.23		.11	9.6	1.1	11.9	5.6
5	S-32-2-2	2-5.5			7.7			-		.03				.35	.30	3.0	.3		41.8	0.13		.13	26.0	.5	20.8	9.9
6	S32-2-3	5.5-10			7.3			3		.08				.51	.54	5.0	.4		42.6	0.21		.14	27.4	.5	24.0	8.2
7	S32-2-4	10-20			7.5			3		.09				.63	1.70	5.0	1.1		40.2	0.20		.19	18.0	1.0	19.1	5.8
	8030																									
8	S6-1-1-74	0-18			7.6			3		.07				.50	.60	5.0	.4		34.4	0.17		.16	13.0	1.2	12.3	5.1
9	Control	0-18			7.7			3		.06				.41	.52	4.8	.3		34.5	0.17		.12	12.8	0.9	11.9	5.4
	8001																									
10	S12-1-1-74	0-32			7.8			3						.42	1.2	4.0	.9		48.1	0.19		.18	32.0	.5	29.5	14.3
11	S12-1-2-74	32-60			8.0			3		.14				.73	5.4	2.8	4.6		47.1	0.13		1.15	37.4	3.0	27.9	14.9
	8020																									
12	S30-1-1-74	0-18			8.0			3		.08				.46	.85	4.0	.6		39.8	0.16		.17	16.0	1.0	13.8	6.8
13	S30-1-2	18-48			8.7			3		.14				.87	7.9	1.0	11.0		27.7	0.03		.74	11.0	6.7	10.6	4.5
	8010																									
14	S30-2-1-74	0-2			8.0			1		.04				.46			.1		25.4	.10		.03	6.2	.4	8.1	3.3
15	S30-2-2	2-14			8.1			2		.08				.44			.3		41.8	.17		.12	22.2	.5	16.8	7.4
16	S30-2-3	14-36			8.4			3		.11							.		32.3	.13		.27	14.2	1.9	15.0	5.6

Table 17 - continued

Boring Number	Depth (inches)	Texture	Particle Size Distribution			Sat.%	$ECx10^3$ Sat. Ex	Soluble Cations me./l				Soluble Anions me/l			
			Sand	Silt	Clay			Ca	Mg	Na	K	CO3	HCO3	SO4	Cl
8020															
S32-1-1-74	0-18	SCL	65.6	13.2	21.2	33.0	0.73	0.40	0.60	6.60	0.06	0.31	4.72	1.61	1.02
S32-1-2	18-36					62.9	3.42	4.52	4.48	28.9	0.23	-	4.39	19.02	14.72
Control - S32-1-3-74	0-36	SCL	66.2	12.6	21.2	28.6	0.69	1.00	1.00	6.00	0.06	0.33	4.31	2.04	1.38
8030															
S32-2-1-74	0-2	SL	62.4	20.4	17.2	33.1	0.61	4.12	2.88	0.36	0.38	0.13	5.55	1.55	0.51
S32-2-2	2-5.5	CL	44.4	20.4	35.2	41.8	0.35	2.56	0.44	0.30	0.05				
S32-2-3	5.5-10	SCL	46.4	24.4	29.2	42.6	0.51	3.56	1.44	0.54	0.04	0.28	5.39	0.23	0.39
S32-2-4	10-20	SL	49.6	20.2	20.2	40.2	0.63	3.00	2.00	1.70	0.04	0.33	4.91	0.68	0.82
8030															
S6-1-1-74	0-18	SL	59.6	25.2	15.2	34.4	0.50	3.36	1.64	0.60	0.18	0.26	3.94	1.13	0.45
Control - S6-1-1-74	0-18	SL	62.6	22.0	15.4	34.5	0.41	2.76	2.04	0.52	0.14	0.20	3.21	1.66	0.39

Table 17 - continued

Boring Number	Depth (inches)	Texture	Particle Size Distribution			Sat.%	$ECx10^3$ Sat. Ex	Soluble Cations me./l				Soluble Anions me/l			
			Sand	Silt	Clay			Ca	Mg	Na	K	CO3	HCO3	SO4	Cl
8001															
S12-1-1-74	0-32	C	19.0	29.8	51.2	48.1	0.42	1.96	2.04	1.20	0.13	0.13	2.82	1.31	1.07
S12-1-2-74	32-60	C	19.2	31.6	49.2	47.1	0.73	0.64	2.16	5.40	0.05				
8020															
S30-1-1-74	0-18	SL	60.0	22.6	17.4	39.8	0.46	2.84	1.16	0.85	0.10	-	4.34	0.24	0.37
S30-1-2-74	18-48	SL	65.4	19.4	15.2	27.7	0.87	0.60	0.40	7.90	0.07	-	3.78	3.95	1.24
8010															
S30-2-1-74	0-2	SL	73.6	19.2	7.2	25.4	0.46	2.96	1.04	0.15	0.58	-	3.63	0.79	0.31
S30-2-2-74	2-14	SCL	57.6	19.2	23.2	41.8	0.44	3.08	0.92	0.40	0.07	-	3.78	0.30	0.39
S30-2-3-74	14-36	SL	53.8	31.0	15.2	32.3	0.55	2.48	2.62	0.50	0.19	0.10	4.43	0.72	0.54

Table 18
OVERBURDEN MATERIAL
LABORATORY RESULTS

Lab Number	Site Number	Depth Feet	Hydraulic Conductivity Ins./hr. 6th Hr.	Hydraulic Conductivity Ins./hr. 24th Hr.	pH 1:5	pH $CaCl_2$ .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	1:5 Extract ecx10^3 @ 25 c	1:5 Extract Ca+Mg Me/L	1:5 Extract SAR Est.	1:5 Extract Ca+Mg Me/100g	Saturation Extract ecx10^3 @ 25 c	Saturation Extract Na Me/L	Saturation Extract Ca+Mg Me/L	Saturation Extract SAR True	Saturation Extract SAR Est.	Saturation Extract Sat. %	Saturation Extract Ca+Mg Me/100g	Gyp. Me 100g	Na Me/100g Exch. Na	Na Me/100g Cation Exchange Capacity	ESP %	% of Moisture Atmosphere 1/3	% of Moisture Atmosphere 15
1	D-9001-1	0-1.5	.760	.640	7.2			2	3	.11				.41	.41	4.2	0.1		34.0	0.14		.11	32.2	0.3	19.7	9.6
2	-1A	1.5-3.4	.276	.228	5.9	4.1		-	3	.07												*.06	111.6			36.9
3	-2	3.4-7.7	.244	.276	6.4			-	3	1.97				8.03	21.9	117.2	2.9		50.8	5.95		.10	21.8		27.0	13.2
4	-3	7.7-9.8	1.080	1.000	7.0			-	3	.34												*.08	3.6			4.0
5	-4	9.8-15.0	.363	.318	5.6	4.6		-	3	1.07				4.82	5.4	77.0	0.9		42.6	3.28		.02	17.0			11.1
6	-5	15.0-21.5	.700	.630	4.4	4.0		-	3	1.03				6.97	6.5	87.0	1.0		33.5	2.91		.10	23.8			10.8
7	-6	21.5-24.7	4.960	1.660	4.6	4.2		-	3	.26				2.72	1.7	24.0	0.5		28.3	0.68		.02	3.2			3.3
8	-7	24.7-29.0	.018	.078	6.0	5.4		-	3	.83				5.20	3.7	77.0	0.6		32.5	2.5		.03	12.8			7.5
9	-8	29.0-35.0	.444	.986	6.0	5.5		-	3	.76				4.49	3.5	67.0	0.6		47.0	3.15		.02	20.8			10.0
10	-9	35.0-41.0	.316	.444	6.6			-	3	.76				2.33	2.8	27.0	0.8		41.0	1.11		.03	15.0	0.2		10.1
11	-10	41.0-48.0	.348	.640	6.9			-	3	.24												*.08	12.0		21.8	9.1
12	-11	48.0-56.6	.278	.320	7.0			-	3	.25												*.08	11.6		19.7	7.8
13	-12	56.6-60.6	1.780	.566	6.9			-	3	.24												*.02	2.8			3.7
14	-13	60.6-67.0	.108	.026	6.9			-	3	.29												*.02	6.8		19.6	6.7
15	-14	67.0-74.6	2.360	1.290	6.9			-	3	.20												*.02	1.2			2.7
16	-15	74.6-83.5	.100	.056	7.3			-	3	.25												*.08	19.2		23.3	9.2
17	-16	83.5-93.5	.188	.138	7.3			-	3	.26												*.04	11.0		21.3	7.8
18	-17	93.5-103.5	.304	.110	7.3			-	3	.28												*.10	11.0		16.9	7.6
19	-18	103.5-108.0	.780	.724	7.0			-	3	.39												*.08	14.0		16.7	8.3
20	-19	108.9-112.4	3.140	.820	7.1			-	3	.16												*.02	3.2			4.0
Coal																										
21	-20	126.4-132.	.344	.470	5.8	5.5		-	3	.27												.06	18.6		25.9	11.8
22	-21	132.0-143.	.138	.046	6.4			-	3	.13												.06	8.8			6.4
23	-22	143.5-153.	.276	.284	6.5			-	3	.14												.04	7.0			6.5
24	-23	153.5-163.	.400	.820	6.6			-	3	.27												.06	12.6		15.7	7.8
25	-24	163.5-173.	.064	.014	7.3			-	3	.11												*.16	11.0		18.3	8.2
26	-25	173.5-183.	.164	.078	7.4			-	3	.11												*.20	9.2		15.1	6.7
27	-26	183.5-193.	.136	.042	7.5			-	3	.10												*.16	9.8			7.1
28	-27	193.5-201.8	.108	.032	7.6			-	3	.11												*.12	9.0			6.9
29	D-9002-1	0-1.4	.084	.078	7.9			3	3	.21				1.98	13.3	7.0	7.1		34.4	0.24		.34	7.4	4.5	21.1	7.6
30	-2	1.4-5.9	.640	1.190	7.9			2	3	.38												*.80	3.2			4.3
31	-3	5.9-12.0	.228	.262	6.2			-	3	.82				4.49	13.1	53.0	2.6		53.2	2.82		.10	26.4	0.3	25.5	11.7
32	-4	12.0-19.5	.192	.164	5.4	5.0		-	3	.95				5.30	9.0	70.0	1.5		57.1	4.0		.09	36.4	0.2		13.7
33	-5	19.5-24.8	.900	.830	4.5	4.4		-	3	.56				3.71	6.4	44.8	1.3		54.0	2.42		.15	40.0	0.3	28.3	16.7
34	-6	24.8-30.4	.224	.318	5.9	5.3		-	3	.41												*.24	21.8			12.2
35	-7	30.4-32.5	.280	.262	6.2			-	3	.30												*.10	6.4		16.3	6.0
36	-8	32.5-37.0	1.340	1.044	6.3			-	3	.19												*.08	2.6		8.9	3.5
37	-9	37.0-43.9	1.440	.956	6.3			-	3	.16												*.14	1.8			2.4
38	-10	43.9-48.4	.308	.660	6.3			-	3	.32												*.28	20.0		22.2	10.3
39	-11	48.4-53.5	.060	.032	7.0			-	3	.20												*.24	13.4		22.6	8.4
40	-12	53.5-61.7	.126	.104	7.2			-	3	.20												*.18	8.2			7.1
41	-13	61.7-67.6	.940	.650	5.5	5.5		-	3	.15												*.12	2.6			3.8
42	-14	67.6-69.3	.228	.220	6.0	5.8		-	3	.19												*.20	13.0		21.8	8.0
43	-15	75.5-80.0	-	.004	7.2			-	3	.19												*1.2	28.0		29.1	12.9
44	-16	80.0-85.0	-	.006	7.7			-	3	.21												*1.2	22.8		26.0	12.3
45	-17	85.0-89.1	.156	.070	7.3			-	3	.33												*2.0	33.6		27.9	15.0
46	-18	89.1-94.0	.436	.700	7.8			3	3	.19												*.58	9.4		15.3	7.0
47	-19	94.0-99.0	.098	.060	7.9			3	3	.17												*.30	4.0			22.6
48	-20	99.0-104.7	.200	.170	7.7			3	3	.18												*.26	2.8			3.9
49	-21	107.2-115.0	-	-	8.7			-	3	.22												*3.6	26.2		30.3	13.6
50	-22	115.0-121.1	-	-	8.6			-	3	.21												*4.2	26.0			15.8
51	-23	121.1-128.5	.036	.054	8.7			1	3	.21				1.72	14.0	2.4	13		31.6	0.08		.54	4.2	12.8		5.4
52	-24	128.5-136.1	-	.016	8.5			2	3	.20				2.38	18.8	4.6	12		32.0	0.15		.72	7.0	10.2		6.4
53	-25	136.1-142.0	-	-	8.8			2	3	.28				1.89	16.8	2.2	16		52.3	0.12		1.92	17.0	11.2		10.5
54	-26	142.0-148.4	-	-	9.1			2	3	.31				1.66	15.0	1.6	17		54.6	0.09		3.78	26.4	14.3		13.4
55	-27	148.4-150.5	1.242	1.966	8.7			2	3	.14				1.35	10.0	2.4	9.1		29.6	0.07		.08	0.8	10.0	5.2	1.2
56	-28	150.5-154.9	-	-	9.0			-	3	.28				1.62	14.7	1.2	19		56.9	0.07		5.56	28.0	19.8		16.8
57	-29	154.9-160.0	-	-	9.2			2	3	.26				1.90	17.3	1.6	19		33.8	0.05		1.38	8.4	16.4		7.2
58	-30	160.0-167.3	-	-	9.3			1	3	.25				2.10	19.9	1.0	28		41.8	0.04		3.57	16.0	22.3		10.2
59	-31	167.3-169.5	.156	.686	8.5			-	3	.37				3.73	36.0	3.72	27		47.6	0.18		6.09	31.0	19.6		13.1
60	-32	169.5-175.	-	-	9.4			3	3	.31				1.68	17.1	0.68	29		34.7	0.02		2.41	9.0	26.7		9.0

*Total Na

Table 18 - continued

Lab Number	Site Number	Depth Feet	Hydraulic Conductivity Ins./hr. 6th Hr.	24th Hr.	pH 1:5	pH $CaCl_2$ .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	1:5 Extract ecx10^3 @ 25 c	Ca+Mg Me/L	SAR Est.	Ca+Mg Me/100g	Saturation Extract ecx10^3 @ 25 c	Na Me/L	Ca+Mg Me/L	SAR True	SAR Est.	Sat. %	Ca+Mg Me/100g	Gyp. Me 100g	Na Me/100g Exch. Na	Cation Exchange Capacity	ESP %	% of Moisture Atmosphere 1/3	15
61	D-9002-33	175.0-180.0	-	-	9.2			3	3	.32				1.71	17.6	0.6	32		44.8	0.03		4.01	14.8	27.0		11.2
62	-34	180.0-186.5	-	.001	9.2			2	3	.25				1.83	18.2	0.8	29		30.1	0.02		1.65	8.0	20.6		6.9
63	-35	186.5-193.5	-	-	9.3			1	3	.35				1.89	18.0	1.12	24		50.2	0.06		6.50	24.0	27.0		15.3
64	-36	193.5-200.8	-	-	9.3			1	3	.28				1.99	20.1	0.8	32		50.9	0.04		5.38	21.4	25.1	35.5	16.5
65	D-9003- 1	0 - 1.3	1.106	1.100	8.2			3	3	.09				0.38	0.3	3.8	0.2		31.5	0.12		0.11	14.0	0.7	16.7	8.1
66	- 2	1.3- 3.9	-	.006	8.5			3	3	.41				4.15	34.0	11.6	14		33.1	0.38		0.67	9.8	6.8		6.8
67	- 3	3.9- 4.6	1.320	1.160	8.5			3	3	.44				5.53	44.0	22.4	13		26.3	0.59		0.04	2.6	1.5		2.5
68	- 4	4.6- 9.6	.128	.116	7.7			1	3	.90				4.89	13.3	59.0	2.4		45.2	2.67		0.2	24.2	0.8		12.0
69	- 5	9.6- 14.9	.660	.680	7.7			2	3	.58				4.61	9.0	58.0	1.7		34.8	2.02		0.07	17.8	0.3	17.1	9.1
70	- 6	14.9- 19.0	.256	.232	8.0			3	3	.36												* .40	17.0		18.5	8.6
71	- 7	19.0- 24.2	.300	.284	6.9			3	3	.40												* .60	33.0		24.3	10.7
72	- 8	24.2- 29.3	.200	.142	7.0			-	3	.40												* .62	31.0		26.2	11.7
73	- 9	29.3- 34.8	.112	.094	7.1			-	3	.46												* .62	34.4			11.0
74	-10	34.8- 42.4	2.092	.944	6.7			-	3	.79				4.22	4.4	60.4	0.8		30.2	1.82		0.05	3.6	1.3		2.8
75	-11	42.4- 49.2	.060	.054	7.0			1	3	.42												* .56	28.0			9.9
76	-12	49.2- 62.6	2.872	1.480	7.0			3	3	.54												* .14	2.0			1.3
77	-13	62.6- 72.4	.092	.086	7.5			-	3	.23												* .40	27.4		24.5	9.7
78	-14	72.4- 80.0	.334	1.120	7.5			-	3	.16												* .10	2.0		8.1	2.4
79	-15	80.0- 88.9	2.022	.720	7.4			-	3	.16												* .12	2.4			2.7
80	-16	88.9- 98.2	.195	.070	7.6			-	3	.19				1.58	2.5	14.8	0.9		37.3	0.55		.11	16.8	.6	19.0	8.1
81	-17	98.2-102.6	3.080	.820	6.9			2		.23												* .10	2.0		7.3	2.1
82	-18	102.6-113.5	.268	.096	7.1			-		.29												* .12	9.0		16.8	5.7
83	-19	113.5-123.5	.328	.392	7.2			-		.19												* .14	7.2			5.7
84	-20	123.5-133.5	.432	.432	7.1			-		.21												* .16	7.4		14.1	5.3
85	-21	133.5-142.4	.166	.200	7.2			-		.22												* .26	18.0		22.5	8.6
85-A	-22	142.4-150.4	.154	.046	7.4			-		.17												* .22	9.6			5.8
86	D-9004- 1	0 - 2.0	.840	.660	7.3			3		.15												* .72	17.4		23.3	10.9
87	- 2	2.0- 7.0	.146	.144	6.9			-		1.35				4.1	10.4	53.2	2.0		51.5	2.74		.17	36.0	.4	27.8	13.4
88	- 3	7.0- 10.0	.372	.328	7.1			-		.53				4.1	7.2	54.8	1.4		47.3	2.59		.22	8.8	-	18.9	5.1
89	- 4	10.0- 13.0	.260	.244	7.5			-		.25												* .18	8.4		18.7	5.5
90	- 5	13.0- 16.0	.436	.380	7.5			2		.23												* .14	7.0		16.2	4.6
91	- 6	16.0- 19.2	.216	.236	7.6			3		.22												* .16	9.2		15.8	5.4
92	- 7	19.2- 21.6	.224	.166	7.3			-		.49												* .18	34.0		26.0	10.4
93	- 8	21.6- 24.3	.164	.150	6.9			1		.14												* .08	15.0		21.6	7.4
94	- 9	24.3- 26.5	.780	.508	7.1			3		.16												* .14	4.6			3.9
95	-10	26.5- 30.5	.224	.220	7.2			2		.16												* .12	10.0		19.0	5.8
96	-11	30.5- 33.5	1.440	.760	7.3			3		.13												* .04	2.8		10.3	2.5
97	-12	33.5- 37.1	.980	.720	7.4			3		.14												* .06	3.2			2.6
98	-13	37.1- 42.0	.166	.160	7.5			1		.18												* .10	9.4			5.3
99	-14	48.9- 53.5	-	.010	7.7			-		.28				1.90	11.0	10.2	4.9		48.0	0.49		.65	27.0	2.4	27.4	10.6
100	-15	53.5- 58.5	-	.016	8.4			-		.26				1.96	14.1	6.4	7.9		44.7	0.29		1.09	26.0	4.1		10.9
101	-16	58.5- 63.0	-	-	9.0			-		.24				1.36	11.7	1.4	14		52.3	0.07		2.59	29.2	8.8		16.1
102	-17	63.0- 67.0	-	-	9.0			-		.26				1.74	15.5	2.4	14		42.8	0.1		1.74	18.8	9.2	24.6	10.8
103	-18	67.0- 72.0	-	-	9.0			-		.32				1.95	17.0	2.4	16		50.1	0.12		2.63	30.0	8.7	29.0	13.5
104	-19	72.0- 77.0	-	-	9.3			-		.30				1.41	12.9	0.8	20		55.9	0.04		3.08	26.2	11.8		17.3
105	-20	77.0- 82.0	-	-	9.4			-		.27				1.62	14.8	1.28	18		41.6	0.05		1.78	14.4	12.4		12.6
106	-21	82.0- 88.0	-	-	9.3			-		.17				1.76	16.0	1.36	19		34.7	0.05		1.20	10.0	12.0		7.8
107	-22	88.0- 93.5	.264	.460	9.0			3		.15				1.44	13.3	2.4	12		28.3	0.07		0.04	1.7	2.4	7.5	2.2
108	-23	93.5- 98.0	1.204	.680	9.0			3		.17				1.87	15.5	4.0	11		25.5	0.10		0.18	1.5	12.0		1.7
109	-24	98.0-104.2	.164	.364	8.8			-		.16				2.04	17.8	3.8	13		25.2	0.10		0.13	1.6	8.1	7.6	2.0
110	-25	104.2-111.0	-	-	9.2			-		.18				1.44	14.2	1.0	20		39.7	0.04		1.84	13.0	14.2		8.1
111	-26	112.3-114.1	.040	.070	9.0			2		.24				2.01	18.5	2.2	18		30.9	0.07		0.83	7.2	11.5	13.9	5.2
112	-27	122.8-129.0	.032	.010	8.7			-		.17				1.40	10.2	3.8	7.4		37.0	0.14		0.2	6.8	2.9	18.2	6.0
113	-28	129.0-134.0	.148	.114	8.3			-		.16				1.56	10.0	6.2	5.7		28.6	0.18		0.03	2.4	1.2	12.5	3.6
114	-29	134.0-139.0	1.060	.388	8.4			-		.14				1.44	9.0	6.32	5.1		27.4	0.17		0.03	1.0	3.0		2.0
115	-30	139.0-144.0	2.420	.540	8.4			-		.14				1.38	8.4	6.08	4.8		32.7	0.20		0.03	1.0	3.0		2.0
116	-31	144.0-154.0	1.102	.640	8.3			-		.15				1.57	10.8	6.08	6.2		29.5	0.18		0.02	1.2	1.7		1.8
117	-32	154.0-164.7	-	.018	8.4			-		.16				2.03	16.0	4.24	11		27.4	0.12		0.16	2.8	5.7		3.1
118	-33	164.7-172.8	1.620	1.080	7.9			-		.12				1.69	12.5	5.12	7.8		30.5	0.16		0.02	.74	2.7		1.1
119	-34	172.8-179.0	-	-	9.0			-		.26				1.45	13.7	1.0	19		53.0	0.05		2.87	24.4	11.8		15.9
120	-35	179.0-186.7	-	-	8.2			-		.22				1.91	18.2	1.6	20		46.3	0.07		2.46	20.4	12.0	28.2	10.5
121	-36	186.7-194.8	-	-	8.4			-		.13				1.67	15.5	1.48	18		27.2	0.04		0.20	3.2	6.2		4.0
122	-37	194.8-201.4	-	-	8.9			-		.34				1.85	17.9	0.92	26		66.7	0.06		6.41	34.2	18.7		19.8

*Total Na

Table 18 - continued

Lab Number	Site Number	Depth Feet	Hydraulic Conductivity Ins./hr. 6th Hr.	Hydraulic Conductivity Ins./hr. 24th Hr.	pH 1:5	pH $CaCl_2$ .01M	Settling Volume ML	Lime Qual.	Gyp. Qual.	1:5 Extract $ecx10^3$ @ 25 c	1:5 Extract Ca+Mg Me/L	1:5 Extract SAR Est.	1:5 Extract Ca+Mg Me/100g	Saturation Extract $ecx10^3$ @ 25 c	Saturation Extract Na Me/L	Saturation Extract Ca+Mg Me/L	Saturation Extract SAR True	Saturation Extract SAR Est.	Saturation Extract Sat. %	Saturation Extract Ca+Mg Me/100g	Gyp. Me 100g	Na Me/100g Exch. Na	Na Me/100g Cation Exchange Capacity	ESP %	% of Moisture Atmosphere 1/3	% of Moisture Atmosphere 15
123	D-9005-1	0 - 1.1	1.144	.820	7.1			1		.82				3.35	14.0	34.4	3.4		48.3	1.66		0.50	36.0	1.4	27.1	11.9
124	-2	3.5- 9.0	.074	.050	7.0			-		.78				5.49	25.7	53.6	5.0		60.6	3.25		1.04	52.0	2.0	32.0	14.7
125	-3	9.0- 19.0	.178	.248	5.3	5.1		-		1.11				6.61	20.7	80.72	3.3		44.8	3.62		0.23	31.8	0.7	23.9	10.4
126	-4	19.0- 35.0	.160	.160	5.3	4.9		-		.68				5.44	17.8	60.48	3.2		44.1	2.67		0.26	38.4	0.7		10.8
127	-5	35.0- 49.7	-	.001	6.7			-		.20												*1.54	28.0		26.4	10.4
128	-6	50.5- 58.2	-	-	8.6			-		.18												*3.60	28.0		27.7	13.6
129	-7	58.2- 65.3	-	-	9.1			-		.18				1.44	13.9	0.72	23		28.8	0.02		0.94	9.0	10.4		6.3
130	-8	65.3- 71.5	-	-	9.1			-		.20				1.28	12.0	0.72	20		40.4	0.03		2.52	19.0	13.3		11.0
131	-9	76.4- 92.4	-	-	9.1			-		.22				1.38	13.7	0.52	27		39.2	0.02		2.26	17.2	13.1		11.6
132	-10	98.2-113.2	-	.040	8.9			1		.26				2.02	19.7	1.32	24		25.4	0.03		1.16	10.4	11.2		6.2
133	-11	117.0-137.2	-	.760	9.0			-		.12				1.05	9.6	0.4	21		28.7	0.01		0.04	1.3	3.1		1.7
134	-12	137.2-146.5	-	-	9.0			-		.29				2.04	20.2	0.76	33		40.7	0.03		4.18	24.0	17.4		12.5
135	-13	146.5-169.7	-	.001	9.2			-		.16				1.27	12.0	0.72	20		27.4	0.02		6.27	3.2	19.6		3.2
136	-14	170.5-196.5	-	-	9.3			-		.20				1.44	13.9	0.6	25		25.4	0.02		0.71	4.8	14.8		4.8
137	D-9006-1	0 - 1.3	2.900	1.040	8.2			3		.11												*0.20	25.8		24.3	8.9
138	-1A	1.3- 2.5	.700	.540	8.8			3		.16												*0.80	27.0		18.2	7.6
139	-2	6.6- 11.0	.860	.450	6.0	4.7		-		.20												*0.10	9.8		13.6	5.2
140	-3	11.0- 29.0	.340	.348	4.8	4.7		-		.78												*0.40	37.0		22.4	11.4
141	-4	29.0- 44.4	.544	.380	6.1	5.5		-		.43												*0.12	3.4		10.5	3.6
142	-5	46.6- 53.5	-	.001	6.5			-		.26				2.20	14.6	7.4	7.6		36.3	0.27		0.27	12.4	2.2	21.5	6.8
143	-6	58.3- 84.5	-	-	8.2			-		.18				1.03	9.7	0.68	17		43.2	0.03		1.98	19.0	10.4	28.3	13.1
144	-7	84.5- 98.6	-	-	7.9			-		.24				2.00	17.9	2.04	18		30.6	0.06		0.47	5.2	9.0		15.1
145	-8	98.6-100.0	-	-	8.3			-		.21				1.27	11.6	0.8	18		50.8	0.04		3.61	19.0	19.0		7.2
146	D-9007-1	0 - 2.7	.392	.488	7.5			3		.18												*0.52	18.0		25.5	8.6
147	-2	5.8- 16.6	4.960	1.060	7.3			3		.21												*0.12	2.6		7.3	1.9
148	-3	16.6- 24.5	2.550	.700	5.9	5.0		-		.78				4.61	5.5	58.4	1.0		30.5	1.78		0.01	18.0	0.05	14.0	7.4
149	-4	35.5- 55.1	.076	.102	6.6			-		.30												*0.14	4.0			5.2
150	-5	56.3- 65.0	.172	.084	6.9			2		.24												*0.10	3.4			4.4
151	-6	66.8- 82.5	.356	.404	6.9			2		.27												*0.16	6.6			5.6
152	-7	93.5-106.3	2.054	.580	7.1			-		.24												*0.06	1.4			2.7
153	D-9008-1	0 - 1.0	.880	1.066	7.3			3		.15												*0.20	16.0		23.4	8.4
154	-2	1.0- 7.4	.322	.440	7.6			3		.30												*0.58	6.4		14.3	4.2
155	-3	7.4- 11.0	.492	.480	7.5			-		.26												*0.38	6.6		15.6	4.5
156	-4	11.0- 15.6	.062	.060	7.0			-		.22												*0.48	8.6			5.9
157	-5	15.6- 21.4	.300	.380	7.0			-		.18												*0.24	6.4		12.6	4.3
158	-6	21.4- 23.8	.150	.176	6.9			-		.66												*0.60	21.6		25.8	10.1
159	-7	23.8- 29.8	.640	.700	6.4			-		.87				6.10	9.5	93.72	1.4		30.0	2.81		0.02	8.6	0.2	15.3	5.0
160	-8	29.8- 32.7	3.160	1.120	6.5			-		.88				3.92	4.4	57.28	0.8		24.5	1.40		0.05	2.8	1.7	6.1	1.3
161	-9	33.5- 38.2	.134	.108	7.0			-		.42												*0.32	7.6			5.4
162	-10	38.2- 43.5	.410	.436	6.8			-		.46												*0.20	3.6			4.4
163	-11	43.5- 48.3	1.040	.780	6.2			-		.22												*0.16	2.2			3.1
164	-12	48.3- 52.9	.500	.520	6.6			-		.32												*0.80	28.0		24.0	11.5
165	-13	52.9- 57.0	.504	.474	6.7			-		.15												*0.12	1.6			2.6
166	-14	57.0- 63.5	.564	.660	6.8			-		.14												*0.10	1.6			1.9
167	-15	63.5- 67.6	.500	.580	7.0			-		.18												*0.14	1.7			2.7
168	-16	67.6- 70.4	.138	.068	7.0			-		.24												*0.24	6.2			5.1
169	-17	70.4- 73.6	1.324	.820	7.0			-		.19												*0.10	1.2			1.5
170	-18	73.6- 76.5	.170	.204	6.9					.22												*0.22	5.6		12.5	4.8
171	-19	82.7- 84.4	.086	.058	7.1			-		.24												*0.82	17.0		21.2	9.3
172	-20	84.4- 89.1	.120	.166	7.1			-		.21												*0.26	5.0			5.3
173	-21	89.1- 96.0	.920	.760	7.5			3		.17												*0.22	1.6			2.3
174	-22	96.0-103.2	.800	.740	7.5			1		.15				1.02	5.1	4.8	3.3		28.6	0.14		0.06	1.0	6.0		2.0
175	-23	103.2-104.6	.574	1.600	7.5			-		.23				1.54	7.9	7.4	4.1		33.8	0.25		0.47	12.8	3.6	14.0	7.1
176	-24	111.5-117.5	-	.001	7.8			-		.20				1.66	13.7	1.8	14		25.8	0.05		0.39	3.2	12.1		4.5
177	-25	117.5-124.1	-	.006	8.3			2		.22				1.35	11.6	0.32	29		23.4	0.01		0.53	3.2	16.5		3.4
178	-26	124.1-129.5	-	-	8.9			1		.47				1.71	15.5	0.32	39		52.7	0.02		6.98	20.0	34.9		20.6
179	-27	129.5-134.9	-	-	8.6			-		.39				2.40	22.3	0.6	41		50.8	0.03		7.87	20.4	38.5	37.9	20.0
180	-28	134.9-143.5	-	-	9.0			1		.22				1.51	13.5	0.44	29		34.0	0.01		2.54	7.0	36.2	26.3	8.7
181	-29	143.5-153.5	-	-	8.7			-		.36				1.37	12.2	0.48	25		43.7	0.02		3.27	9.0	36.3		10.7
182	-30	153.5-166.8	-	-	8.6			1		.38												*2.60	6.4			6.8
183	-31	166.8-176.7	-	-	8.5			2		.24												*0.92	2.0			2.8
184	-32	176.7-184.2	-	.030	8.2			2		.22												*0.72	1.6			1.9
185	-33	184.2-194.2	-	.044	8.4			-		.18												*0.58	1.6			1.7
186	-34	194.2-203.5	-	.040	8.5			-		.18												0.60	1.4		8.5	1.7
																						*Total	Na			

Table 18 - continued

Boring Number	Depth (feet)	Texture	Particle Size Distribution			Sat.%	$ECx10^3$ Sat. Ex	Soluble Cations me./l				Soluble Anions me/l			
			Sand	Silt	Clay			Ca	Mg	Na	K	CO3	HCO3	SO4	Cl
D-9001-1	0-1.5					34.0	0.41	3.08	1.12	0.41	0.80	0.14	3.75	1.06	0.45
2	3.4-7.7					50.8	8.03	24.7	92.5	21.9	0.42	-	5.78	122	11.4
4	9.8-15.0					42.6	4.82	20.5	56.5	5.40	0.43	-	0.20	80.7	1.91
8	29.0-35.0					47.0	4.49	19.0	48.0	3.50	0.15	-	1.07	69.2	0.36
9	35.0-41.0					41.0	2.33	8.60	18.4	2.80	0.22	0.73	6.13	22.3	0.90
D-9002-1	0-1.4					34.4	1.98	2.72	4.28	13.3	0.94	0.34	5.09	8.76	7.05
3	5.9-12.0					53.2	4.49	12.5	40.5	13.1	0.64	-	3.50	57.9	5.38
4	12.0-19.5					57.1	5.30	21.5	48.5	9.0	0.98	-	0.29	75.6	4.06
27	148.4-150.5					29.6	1.35	1.48	0.92	10.0	0.41	-	4.08	6.85	1.88
D-9003-1	0-1.3					31.5	0.38	2.36	1.44	0.30	0.15	-	3.38	0.58	0.31
4	4.6-9.6					45.2	4.89	26.5	32.5	13.3	0.99	-	2.40	65.6	5.32
10	34.8-42.4					30.2	4.22	28.2	32.2	4.40	0.52	-	2.48	61.2	1.60
D-9004-2	2.0-7.0					51.5	4.10	28.1	25.1	10.4	0.85	-	7.29	55.1	2.11
14	48.9-53.5					48.0	1.90	3.76	6.44	11.0	0.94	-	4.62	17.0	0.50

Table 18 - continued

Boring Number	Depth (feet)	Texture	Particle Size Distribution			Sat.%	$ECx10^3$ Sat. Ex	Soluble Cations me./l				Soluble Anions me/l			
			Sand	Silt	Clay			Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl
D-9004-18	6.70-72.0					50.1	1.95	1.00	1.40	17.0	0.62	-	10.2	9.54	0.31
20	77.0-82.0					41.6	1.62	0.72	0.56	14.8	0.48	0.50	6.48	8.79	0.79
22	88.0-93.5					28.3	1.44	1.40	1.00	13.3	0.46	-	6.39	9.18	0.59
23	93.5-98.0					25.5	1.87	2.84	1.16	15.5	0.49	-	4.82	14.5	0.65
24	98.0-104.2					25.2	2.04	2.96	0.84	17.8	0.49	-	3.84	17.6	0.65
26	112.3-114.1					30.9	2.01	1.32	0.88	18.5	0.61	1.10	7.60	8.32	4.29
27	122.8-129.0					37.0	1.40	2.24	1.56	10.2	0.84	0.46	5.15	8.38	0.85
29	134.0-139.0					27.4	1.44	3.72	2.60	9.00	0.59	-	6.45	8.67	0.79
30	139.0-144.0					32.7	1.38	3.76	2.32	8.40	0.49	-	3.65	10.7	0.65
31	144.0-154.0					29.5	1.57	4.80	1.28	10.8	0.54	-	3.85	12.8	0.79
33	164.7-172.8					30.5	1.69	2.64	2.48	12.5	0.55	-	2.22	14.7	1.30
34	172.8-179.0					53.0	1.45	0.44	0.56	13.7	0.52	0.44	7.74	8.24	0.25
37	194.8-201.4					66.7	1.85	0.40	0.52	17.9	0.48	0.48	10.9	7.54	0.34
D-9005-1	0-1.1					48.3	3.35	29.4	5.00	14.0	0.12	-	5.66	41.6	1.27

Table 18 - continued

Boring Number	Depth (feet)	Texture	Particle Size Distribution %			Sat.%	$ECx10^3$ Sat. Ex	Soluble Cations me./l				Soluble Anions me/l			
			Sand	Silt	Clay			Ca	Mg	Na	K	CO3	HCO3	SO4	Cl
D-9005-2	3.5-9.0					60.6	5.49	20.4	33.2	25.7	0.94	-	0.66	70.8	8.77
3	9.0-19.0					44.8	6.61	21.6	59.1	20.7	1.58	-	0.11	99.5	3.44
11	117.0-137.2					28.7	1.05	0.20	0.20	9.60	0.30	-	8.37	0.94	0.99
D-9006-6	58.3-84.5					43.2	1.03	0.28	0.40	9.70	0.35	0.41	6.29	3.38	0.65
D-9008-7	23.8-29.8					30.0	6.10	25.1	68.6	9.50	1.10	-	0.71	102	1.32
8	29.8-32.7					24.5	3.92	26.3	31.0	4.40	0.41	-	2.92	58.5	0.65
22	96.0-103.2					28.6	1.02	2.40	2.40	5.10	0.48	-	4.16	4.61	1.61

The site locations are shown on exhibits 1, 2, 3, 4, and 5, as well as on the geologic location map plate 2.

Both the chemical and physical laboratory results are considered under the discussion of the Evaluation of Site Soils and Overburden Material as Plant Growth Media later in the report.

Techniques, procedures and standards used in soil investigations

Field investigations

Field investigations of the Hanna study site were initiated in July of 1974 with a reconnaissance of the area to determine general soil types, topography, and probable complexity of the area. Preliminary mapping units were established at this time for soil taxonomic units which were considered to be most prevalent.

As field work progressed, pits were opened, soil profiles examined, and detailed descriptions made of representative soil types within the study area. At this stage of investigations, close contact was maintained with the office of the Wyoming State Soil Scientist of the Soil Conservation Service to assure that soil classification and nomenclature for the study area were compatible with established mapping for this part of Wyoming. The aforementioned profile description and classification process resulted in a working mapping legend for the study area.

As additional work was accomplished and more borings were made, modifications were made to the aforementioned mapping legend in order to make it conform more closely to conditions observed in the field.

Samples for laboratory analysis were taken from pits used for representative profile descriptions as well as from deep borings made in and through the overburden materials. These analyses were used to confirm or modify the existing mapping legend as well as to ascertain the chemical and physical suitability of the materials for revegetation purposes.

Not only were the developed soils of the study site examined, but overburden materials lying between the soils and the underlying coal seams were also closely scrutinized. These overburden materials range in thickness from just a few feet to over 150 feet and probably represent the majority of material which will be used as a plant growth medium since the native soils of the area are quite shallow. Deep hole sites (explored by core drilling equipment) were sampled by taking selected parts of the core for both physical and chemical analyses of the deeper-lying materials (these sites were also used as master locations for soil survey purposes).

Standards established for soils investigations were essentially the same as those commonly used for a detailed or high intensity standard soil survey as accomplished by the Soil Conservation Service. Nomenclature used is compatible with National Soil Classification System standards.

Laboratory Investigations

Chemical and physical characterizations of genetic soil profiles and overburden materials were an important aspect of analyzing the material resources of the Hanna site. Soil samples were taken within the study area and were transported to the laboratory for evaluation. The soil sampling sites are correlated with mapping units and represent typical site chemical and physical characteristics. The overburden material was obtained from drill borings with the drill cores being received in the laboratory at the conclusion of the field program. The deep boring sites were selected on a geological basis and became the master sites for characterizing overburden material in relation to the coal.

In the laboratory the soil samples were analyzed separately from the overburden material and the results of these analyses are shown in table 17. Detailed techniques were used in analyzing the genetic soil profiles. Control samples were analyzed along with the other as well as duplicate analysis where deemed necessary.

After the drill cores were received in the laboratory, they were separated into samples for overburden evaluation. The basis of separation involved geological delineations as well as textural composition. Uniformity was obtained by this procedure, and the majority of the samples are comprised of no more than 5 to 6 feet of the core. Because of the volume of overburden samples, a screening technique was used in characterizing these materials. Electrical conductivities (1:5), pH measurements, hydraulic conductivity (disturbed), lime (qualitative) and sulfate (1:5 qualitative) were run on all samples. Parameters such as greater than .40 EC, reduction in hydraulic conductivity after 24 hour reading (indicating a possible sodic situation), less than 6.5 or greater than 8.2 pH, etc. were established, and those samples that did not meet any one of these parameters were analyzed further. The extent of testing on the overburden materials are shown in table 18.

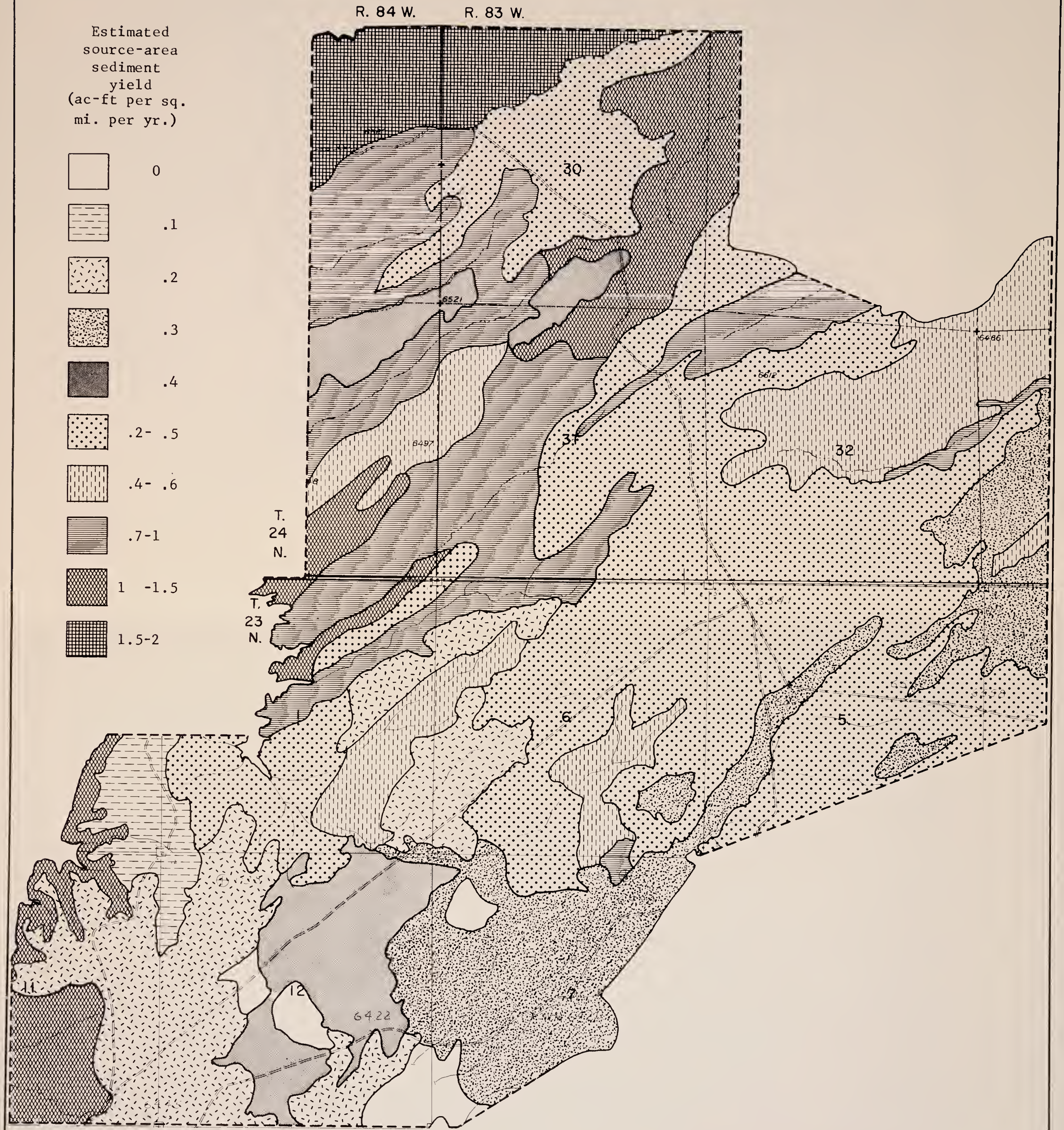
Sediment Yields

Much of the information presented in this section on sediment yields and channel characteristics applies to premining conditions. If the area is mined and reclaimed this information will be useful in evaluating the efficiency of reclamation with respect to erosion and sediment yields. The information should also be useful to those who will design the reconstructed topography if the study area is mined. The sediment yield values presented for this area of ephemeral streamflow were derived using a qualitative rating method and have been judged to be reasonably accurate but they have not been verified by actual measurements.

The method used to obtain the annual source-area sediment yield estimates was the (PSIAC) Pacific Southwest Interagency Committee (1968) method which entails the rating of nine factors: surface geology, soils climate, runoff, topography, ground cover, land use, upland erosion, and channel erosion and sediment transport. While the method was developed to make broad sediment yield classifications for large areas, such as river sub-basins, Shown (1970) found that the method provides reasonable estimates for small drainage basins such as those within the sediment yield types shown on plate 4.

Sediment yield estimates were actually made on 10 relatively homogeneous small watershed areas throughout the study site. Aerial photographs (1:12,000 scale) were then used to extend the estimates to the whole study area. Systematic interpretation of the photographs included consideration of (1) vegetation type, (2) density of the vegetation, (3) landform type, (4) steepness and length of slopes and (5) drainage density. Categories 2, 4, and 5 were rated on a relative basis within the mapped area on a scale ranging from zero to three, which corresponds to none, low, medium and high. These relative values were quantified later (see table 19) using the vegetation measurements shown on table 23, U.S. Geological Survey topographic maps for slope measurements, and the aerial photographs for channel mapping and raw gully density measurements.

Figures 4 and 5 show the relationships of average percent bare soil and average percent slope to annual source-area sediment yields for the study area. The variation in percent bare soil explains 96 percent of the variation in source-area sediment yields, and the variation in percent slope explains 97 percent of the variation in source-area sediment yield. The standard error of estimate of sediment yields is 0.11 acre-feet per square mile for the bare soil relation (fig. 4) and .10 for the slope relation (fig. 5). These relationships could be used to estimate source-area sediment yields for other parts of the Hanna Basin Coal Field, and perhaps other areas, having similar climate, geology, topography, soils, vegetation, and land use.



Base from U.S. Geological Survey
Pat's Bottom and Seminoe Dam SE
7½-minute quadrangles

Plate 4

ESTIMATED ANNUAL SOURCE-AREA SEDIMENT YIELDS FOR THE HANNA BASIN
COAL FIELD STUDY SITE--WYOMING, 1974

Table 19.--Characteristics of the source-area sediment yield mapping units shown on plate

Estimated source-area sediment yield (acre-ft/mi²/yr)	Topography	Slope (percent)	Raw gully density (mi/mi²) 1/	Bare soil (percent)	Surficial Material(s)
0	Playa	0	0	2/ 24	Silty and clayey alluvium
.1	Terrace	0	0	15e	Gravelly loam soil
.2	a. Small flats	0- 1	0	78	Silty alluvium
	b. Rolling	0- 2	0 - 3.5 (1.0)	23	Sandy loam soil
	c. Small aeolian dunes, poorly dissected	1- 4	0 - 1.1 (.3)	8-23	Fine sandy soil
.3	a. Dimpled tableland of low relief, poorly to moderately dissected.	2- 7	0	10e	Fragmented clinker with aeolian fine sand in depressions
.4	b. Flat and gently rolling, poorly dissected	0- 7	0	45-78	Fine sandy loam and silty loam soils
.2- .5	a. Gently rolling, poorly dissected	0- 2	0 - .4 (.2)	8-23	Fine sandy loam soil
	b. Alternating low ridges and shallow valleys poorly to moderately dissected	2- 5	.1- 1.4 (.7)	29-45	Sandy loam soil
.4- .6	Alternating low ridges and shallow valleys, moderately dissected	4- 6	0 -11 (4.7)	29-45	Sandy loam soil
.7-1.0	Dissected low ridges and shallow valleys	4- 9	3.6-16 (7.5)	45-78	Shallow soils on weathered shale and sandstone
1 -1.5	Moderately steep, dissected and relatively barren	6-18	2.1-10 (6.5)	50-80e	Weathered shale and sandstone, clinker fragments, coal outcrops
1.5-2.0	Steep, dissected relatively barren scarp	15-33	8.6	50-90e	Shale, sandstone ledges, clinker, and coal outcrops

1/ Length of unvegetated, gullied channels per square mile of area for channels that are larger than third or fourth order as determined on 1:12,000 scale aerial photographs. The numbers in parentheses are the weighted mean values for the several measurements within the types.

2/ "e" indicates estimated value using measurements at other sites for reference.

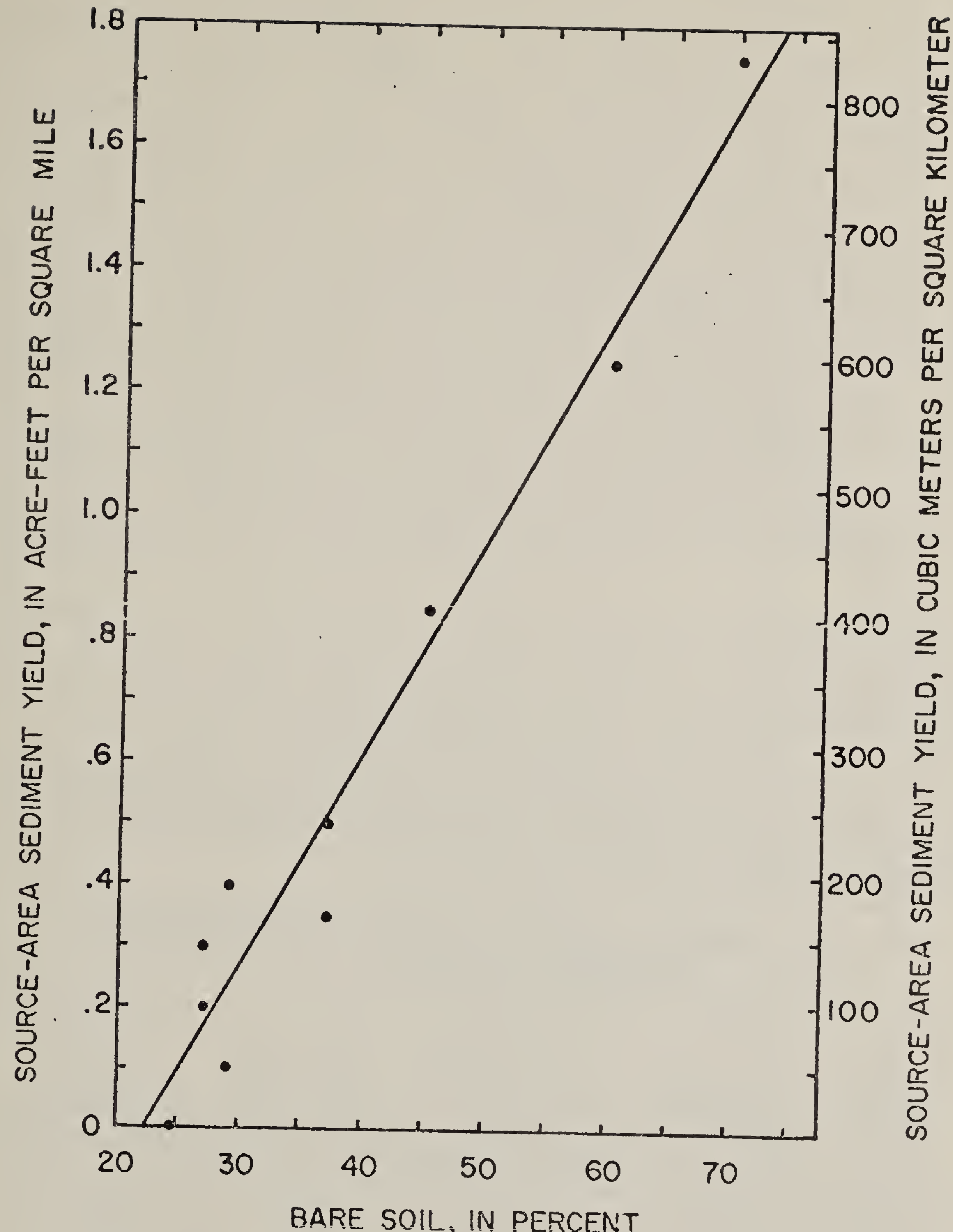


Figure 4.--The relation of estimated source-area sediment yields to the average amounts of bare soil for the sediment yield units shown on Plate 4 for the Hanna Basin Coal Field study site.

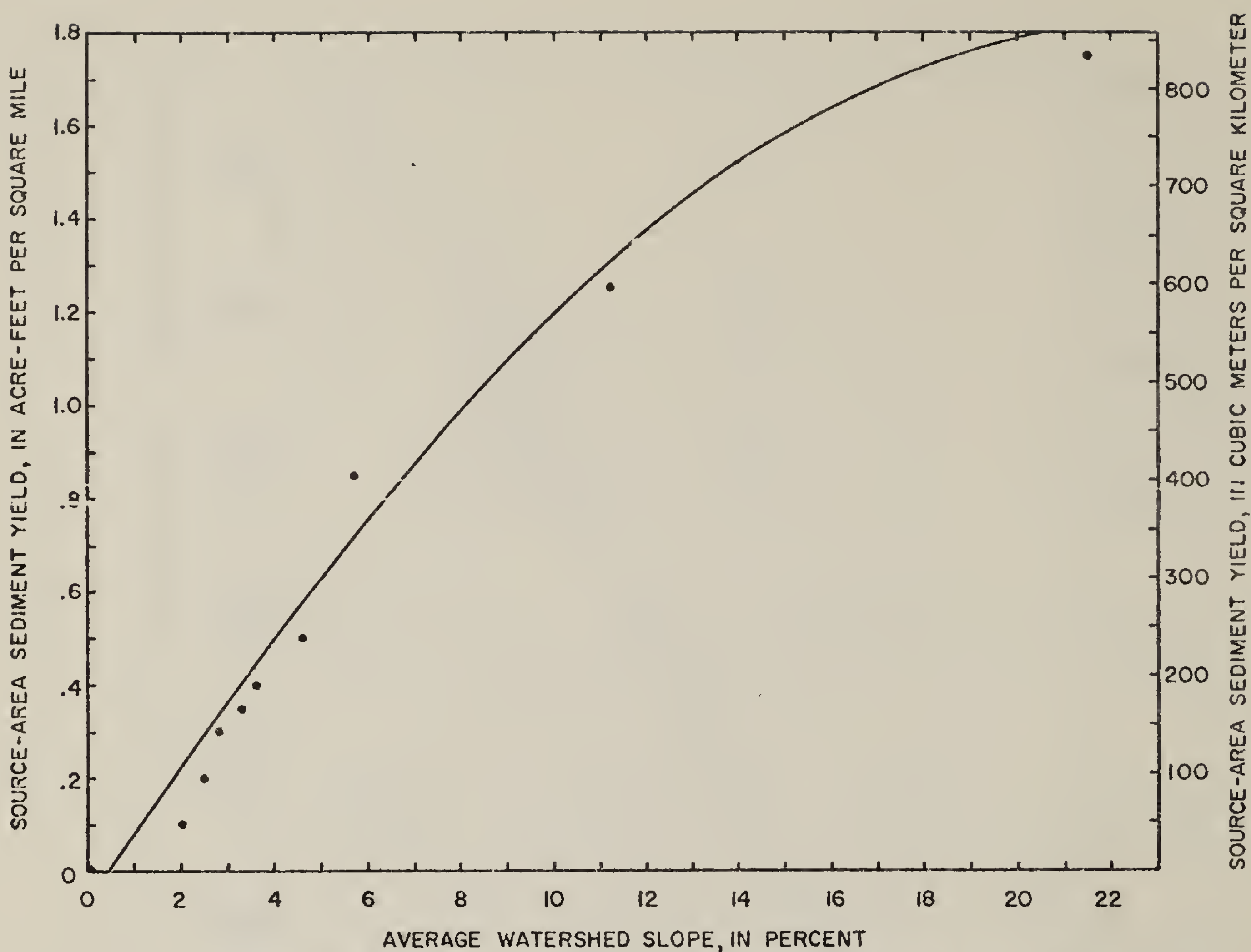


Figure 5 .--The relation of estimated source-area sediment yield to average slope of the sediment yield units shown on Plate 4 for the Hanna Basin Coal Field study site.

Table 20.--Sediment yields from the drainage basins outlined on Plate 5

Basin	Drainage area (mi^2)	Raw gully density (mi/mi^2)	Weighted source-area sediment yield (acre-ft/mi^2)	Sediment delivery factor	Basin sediment yield (acre-ft/mi^2)
A	.06	7.5	1.75	.90	1.6
B	.17	2.9	1.16	.70	.8
C	.30	3.9	.75	.75	.6
D	.13	4.2	.50	.50	.3
E	.11	1.9	.40	.30	.1
F	.64	2.3	.45	.60	.3
G	.12	5.3	,37	.55	.2
H	1.11	2,4	,36	.35	.1
I	.26	2.5	.33	,25	.1
J	.07	4.7	.52	.50	.3
K	.33	2.3	.41	.30	.1

The basin sediment yields shown in table 20 for the small drainage basins outlined on plate 5 were computed by multiplying the area-weighted source-area sediment yield for each basin by a sediment delivery factor based on raw gully density (table 20), on field observations (table 21) and photo interpretation of the channel conditions (plate 5). This was a modification of a rating scheme for obtaining sediment transport factors that was developed in a previous study by Frickel, Shown, and Patton (1975). Their scheme considers the effects on sediment transport by perennial and ephemeral streams, of various conditions such as (1) channel width and gradient, (2) whether the channel is gullied or just a broad, grassy drainageway, (3) the size of the bed material and vegetative cover on the bed, (4) intermittent gullies in the channel system and (5) evidence of deposition in the channels and the occurrence of alluvial fans and deposition on bottomlands where flows spread either naturally or because of man-made impoundments or diversions of water.

Without reference to a mining plan for an area it is difficult to assess the effects that surface mining will have on the sediment yield of that area. None the less, some PSIAC estimates of sediment yields from overburden areas were made under assumed conditions for surface materials, slope and cover as shown in table 22 . The characteristics and reclamation treatments of the overburden banks at the Seminoe Number One Mine about 6 miles south of the study area were used as a guide for arriving at the assumed conditions, realizing that the conditions and reclamation treatments could be somewhat different on this study area. Also, some guidelines for surface mine reclamation prepared by the Soil Conservation Service in Montana (USDA, 1971) were referred to in making assumptions.

Soils or other existing surface materials on the study site that are suitable for use in reclamation are shallow. Therefore, it was assumed that selected materials from within the overburden section would be placed on the surface on parts of the reclaimed area. This material would probably be a sandy clay containing fragments of sandstone. If any clinker is removed during mining, it could be stockpiled and later incorporated with the clay to make a more permeable and less erodible material with which to top the replaced overburden. It was assumed that areas covered with this sandy clay material would be close-spaced contour furrowed (Branson, Miller and McQueen, 1966) or gouger pitted (Sindelar, Hodder and Majerus, 1973) to reduce runoff and erosion and enhance vegetation establishment. Further, it was assumed that adapted grass species would be seeded on all of the replaced overburden and that weather conditions would be favorable for establishment of a cover that probably in 5 years would be in equilibrium with its environment.

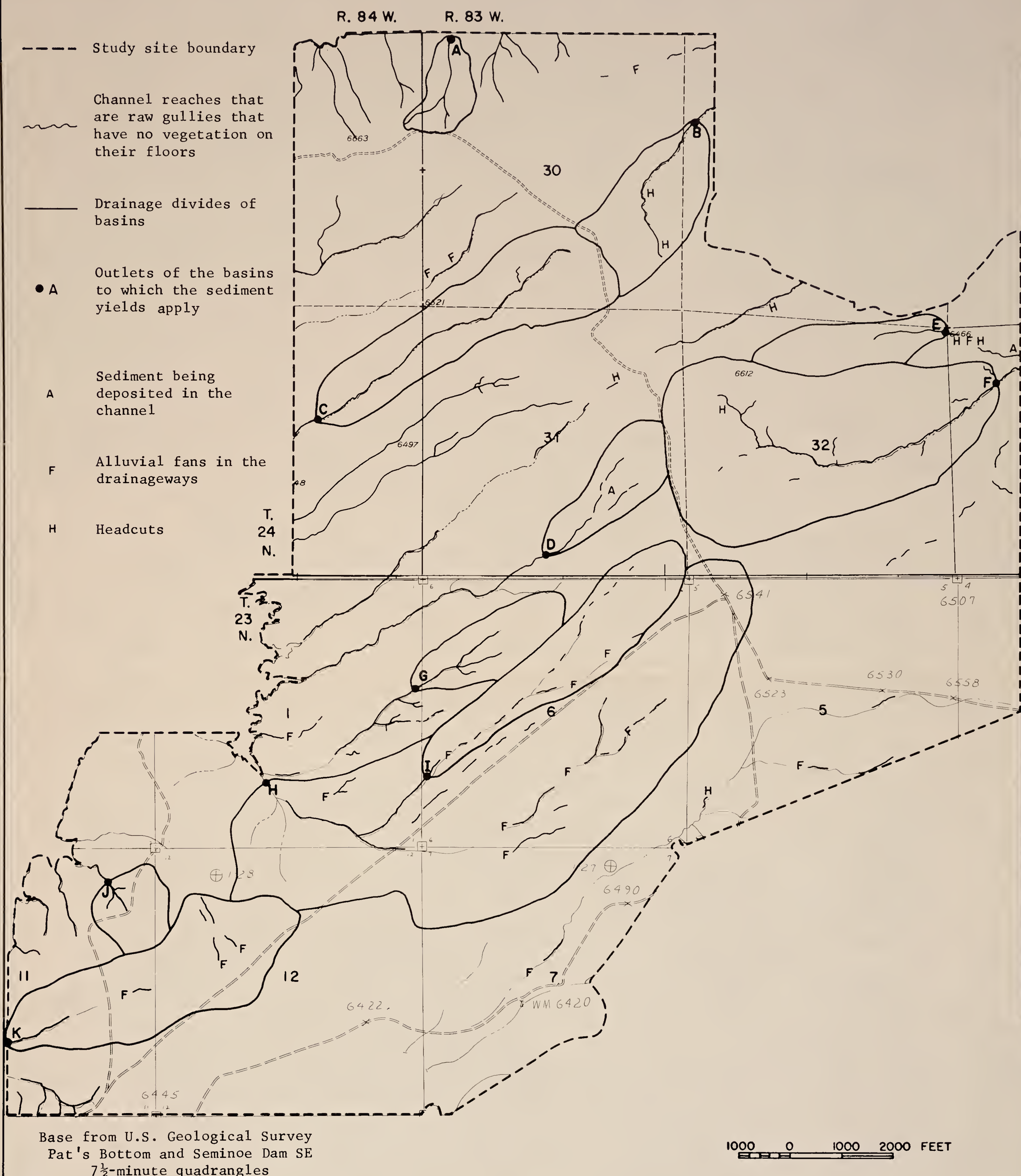


Plate 5

CHANNEL CONDITIONS AND DRAINAGE BASINS FOR WHICH SEDIMENT YIELD ESTIMATES WERE MADE ON THE HANNA BASIN COAL FIELD STUDY SITE--WYOMING, 1974

Table 21--Channel conditions and relative sediment transport at locations indicated on plate 5 .

Channel section	Sediment transport	Outstanding characteristic(s)	Bed material	Bank material	Gradient (percent)	Active channel dimensions Width (ft)	Active channel dimensions Depth (ft)
D	moderate	some sandstone bedrock ledges controlling channel base-level	sand, sandstone chips, 1.5 ft. sandstone fragments	fine sand, gravel	2.5	4	.3
E	low to moderate	gully about 3 ft deep incised in alluvium, grassed flood plain	sand	sandy loam	2	3	.5
G	moderate	raw bed, sloping banks, with sage, alluvium 2-3 ft thick, bottom incised into sandstone bedrock and coal	sand, gravel and sandstone fragments up to 6 in. in size	sandy loam	1	5.5	.3
I (above headcut)	low	braided rills in a sagebrush-covered swale	sandy loam	silt clay loam	1	1 (main rill)	.5
I (below 4-ft. headcut)	moderate	poorly defined channel, headcut advance apparently slow	sand	silty clay loam	2.5	1.5	.3
K (below 3-ft. headcut)	moderate to high	headcut advance apparently slow, narrow gully cut into alluvium	1-ft sandstone fragments, sand, little clay	clay, gravel	2.5	2.2	.15

Table 22.--PSIAC estimates of source-area sediment yields from presumed overburden areas before, during, and after reclamation on the Hanna Basin Coal Field study site

	Surface material	Ungraded overburden banks	Graded overburden			Reclaimed overburden during establishment of vegetation[2]			Reclaimed overburden after establishment of vegetation[3]		
Slope (percent)		80-100	0-5	15	30	0-5	15	30	0-5	15	30
Bare soil (percent)	sandy loam soil	--		95(rock, 5)		40	50	60	20	30	40
	sandy clay overburden[1]	80(rock, 20)		80(rock, 20)		50	60	70	35	45	55
Sediment yield (ac-ft/mi^2)	sandy loam soil	--	.4	.6	.9	.1	.2	.4	.1	.2	.3
	sandy clay overburden	1.5-2.5	.4	.7	1.1	.2	.3	.6	.1	.2	.4

1/ Assumed that this material would be contour furrowed to reduce runoff and erosion and enhance vegetation establishment

2/ Assumed that the area would be protected from grazing during this period. Cover and sediment yield values are averages for the period.

3/ Assumed that there would be moderate grazing

Without some control measures the sediment discharge to Seminoe Reservoir during mining and reclamation would be increased somewhat above the present rates indicated in table 21. The following are some measures that might be used for control of sediment discharge to Seminoe Reservoir: (1) Small reservoirs could be constructed on or near the overburden area and cleaned out periodically, if necessary, to maintain storage capacity. It may be desireable to remove the dam and sediment deposit at the end of the reclamation period to prevent eventual breaching of the dam. (2) The existing playas or closed basins created during the reconstruction of the landscape could be used as sediment traps and ground water recharge facilities. If all or parts of the relatively flat nuttall saltbush and birdfoot sagebrush areas in sections 6 and 12 of T. 23 N., R. 83 and 84W and section 32 T. 24N., R. 83W are not mined, it might be feasible to construct water spreader systems (Miller and others, 1969) to dissipate the sediment-bearing flows on these areas. This assumes that the disturbed overburden areas would be nearby and that a long or elaborate water collection and diversion system was not required to get the water to the spreading areas.

VEGETATION, SOIL MOISTURE RETENTION, AND SOIL ERODIBILITY CHARACTERISTICS

Vegetation

Vegetation was mapped (see plate 6) from false IR color aerial photos, then identifiable vegetation-soil units were sampled to define density of cover (see table 23) and the characteristics of associated soils. Internal-plant stress was measured on shrubs for comparison with measurements of soil moisture stress and as a possible aid in the selection of species for revegetation.

The general aspect of the vegetation is northern desert shrub and is similar to extensive areas in Utah and Nevada. Big sagebrush is the dominant over large areas but birdfoot sagebrush, a species whose distribution is limited almost entirely to the state of Wyoming, also covers a large portion of the site. Several halophytes such as nuttall saltbush, shadscale, and greasewood are common. These salt-desert shrubs are also widely distributed in the other western states. The grasses are nearly all of the cool season type that tolerate the relatively cool climate of the site. The only grass species present that might be classed as warm season is indian ricegrass but it, too, has a wide temperature tolerance. Surprisingly few forbs occur in the area and only two (pussytoes and longleaf phlox) were present in the plots sampled.

General Soil considerations

Reclamation of surface-mined lands will be more successful and accomplished in less time if surface soils are stockpiled and then replaced on the reshaped overburden. Effective use of the surface soils requires a knowledge of their moisture retention characteristic or the relationship between the quantity of moisture in the soil and the forces involved in retaining that moisture.

The moisture retention characteristic for a soil can be defined if two physical properties are known (1) a measure of the surface available within a soil for adsorption of moisture as films. (2) a measure of the porosity of the soil that exists at the time for which the characteristic is to be defined.

Moisture contents may be defined on a weight basis (grams of water per gram of soil) or on a volume basis (cubic centimetres of water per cubic centimetre of soil). Conversions from weight to volume are made through multiplication by the dry bulk density of the soil.

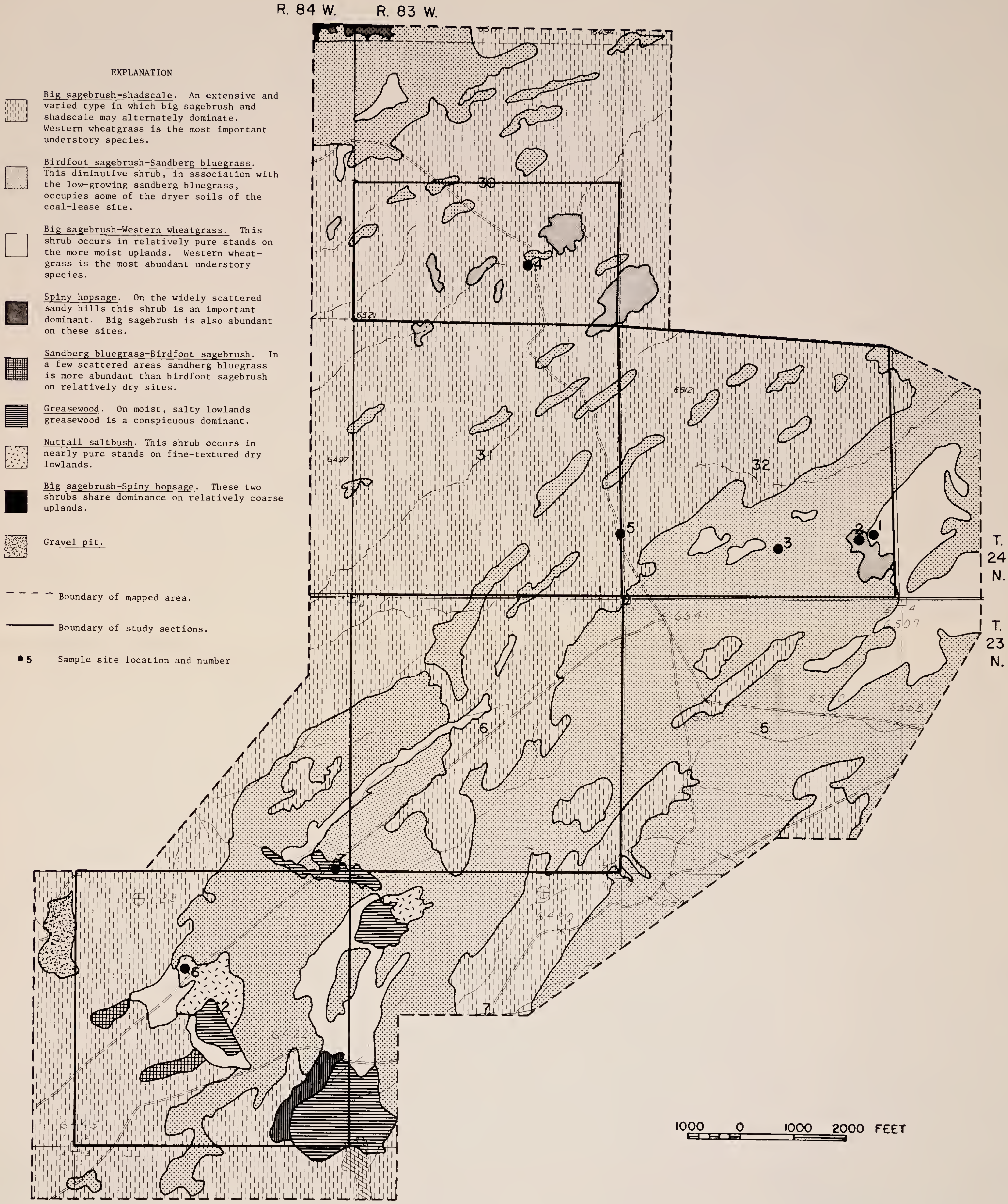


Plate 6

Base from U.S. Geological Survey
Pat's Bottom and Seminoe Dam SE
$7\frac{1}{2}$-minute quadrangles

VEGETATION MAP OF THE HANNA BASIN COAL FIELD

STUDY SITE--WYOMING, 1974

Table 23.--Percentage cover of vegetation, mulch, rock and bare soil at the sites sampled on the Hanna Basin Coal Field Study Site.

	Sampling site number..	5	1	3	4	6	7	2
	Vegetation type.......	Big sagebrush-shadscale	Big sagebrush-Western wheatgrass	Birdfoot sagebrush	Breaks	Nuttall saltbush	Grease-wood	Spiny hopsage
Species								
Shrubs								
Artemisia frigida	Fringed sagewort	--	--	--	--	--	--	1.2
Artemisia pedatifida	Birdfoot sagebrush	--	0.5	15.5	--	--	--	--
Artemisia spinescens	Bud sagebrush	1.5	--	--	--	--	--	--
Artemisia tridentata	Big sagebrush	3.2	13.0	0.5	5.5	--	1.3	11.8
Atriplex confertifolia	Shadscale	5.8	--	--	3.0	--	--	--
Atriplex nuttallii	Nuttall saltbush	--	--	4.0	--	13.8	8.0	--
Chrysothamnus greenei	Greenes rabbitbrush	0.7	--	--	--	--	--	--
Chrysothamnus viscidiflorus	Douglas rabbitbrush	--	--	--	1.0	--	--	--
Grayia spinosa	Spiny hopsage	--	--	--	--	--	--	30.5
Gutierrezia sarothrae	Snakeweed	0.7	--	--	--	--	--	--
Opuntia polyacantha	Plains pricklypear	0.2	--	--	--	--	--	--
Sarcobatus vermiculatus	Greasewood	--	--	--	--	--	35.2	--
Tetradymia spinosa	Spiny horsebrush	1.2	--	--	0.2	--	--	--
Grasses and grass-like								
Agropyron dasystachyum	Thickspike wheatgrass	--	--	--	--	--	--	2.2
Agropyron smithii	Western wheatgrass	24.0	22.5	14.2	3.5	--	11.2	7.0
Agropyron spicatum	Bluebunch wheatgrass	--	2.5	--	7.2	--	--	--
Bromus tectorum	Cheatgrass	--	--	--	--	--	--	6.3
Carex eleocharis	Needleleaf sedge	--	1.5	--	--	--	--	--
Oryzopsis hymenoides	Indian ricegrass	--	--	--	10.8	--	--	--
Poa secunda	Sandberg bluegrass	3.5	6.7	11.8	--	2.7	3.5	4.0
Sitanion hystrix	Squirreltail	1.2	--	--	0.8	--	0.8	--
Stipa comata	Needle-and-thread	--	1.2	--	3.0	--	--	--
Forbs								
Antennaria aprica	Pussytoes	--	0.2	--	--	--	--	--
Phlox longifolia	Longleaf phlox	1.5	1.2	0.3	1.2	--	--	--
Mulch		18.0	28.0	8.5	9.8	5.5	15.8	29.2
Rock		5.0	--	--	24.8	--	--	--
Bare		28.5	23.0	45.2	29.2	78.0	24.2	7.8

The forces of moisture retention are defined in numerous ways. In this section of the report, pF (Schofield, 1935) which is defined as the common logarithm of the height in centimetres of a column of water that requires an equivalent force to support it, will be used to simplify computations and permit visualization of the forces as physical dimensions.

For equilibrium conditions a pF of 1 represents the retention force at a height of 10 centimetres above a water table. At 100 centimetres above a water table the stress would be pF 2 and at 1,000 centimetres the equilibrium stress would be pF 3.0.

McQueen and Miller (1974) described a model for synthesizing the soil moisture characteristic from limited data. The curve is divided into segments and a separate mechanism of moisture retention determines each segment. For the range of retention forces from pF 2.5 to 5.0 moisture is retained as films on particle surfaces by molecular adsorptive forces that vary inversely with a power of the film thickness. This segment of the characteristic is a straight line intersecting the zero moisture content axis at pF 6.25 and passing through any valid pF verus moisture-content data points that are known.

For retention forces greater than pF 5.0 the moisture is adsorbed to surfaces in a pseudomolecular structure and the moisture characteristic is cyclic. However, it can be approximated by a straight line between the zero moisture content axis at pF 7.0 and the adsorbed segment at pF 5.0.

For moisture retention forces less than pF 2.9 surface tension forces may add additional moisture in the form of capillary water bodies to the moisture retained as adsorbed films. This capillary segment of the soil moisture characteristic is unstable, because of alterations in pore geometry and the effects of a hysteresis loop, so it can only be defined in terms of limits or ranges. However, the probable configuration can be predicted for given sets of conditions.

Synthesis of a typical soil moisture characteristic is illustrated in figure 6. The adsorbed water segment is defined from one or more data points. In this report all retention data were obtained with the wide range method of McQueen and Miller (1968) but any valid data could be used. The intercept of the adsorbed water segment at pF 6.25 has been established statistically from a large mass of data and should be considered valid for most soils. Structured water (the segment above pF 5.0) can usually be removed from a soil profile only by evaporation near the soil surface so it need not be considered when computing transpiration. The adsorbed moisture segment is extended to the zero pF axis to indicate the computation for AMC (the maximum adsorbed moisture at a stress of pF zero).

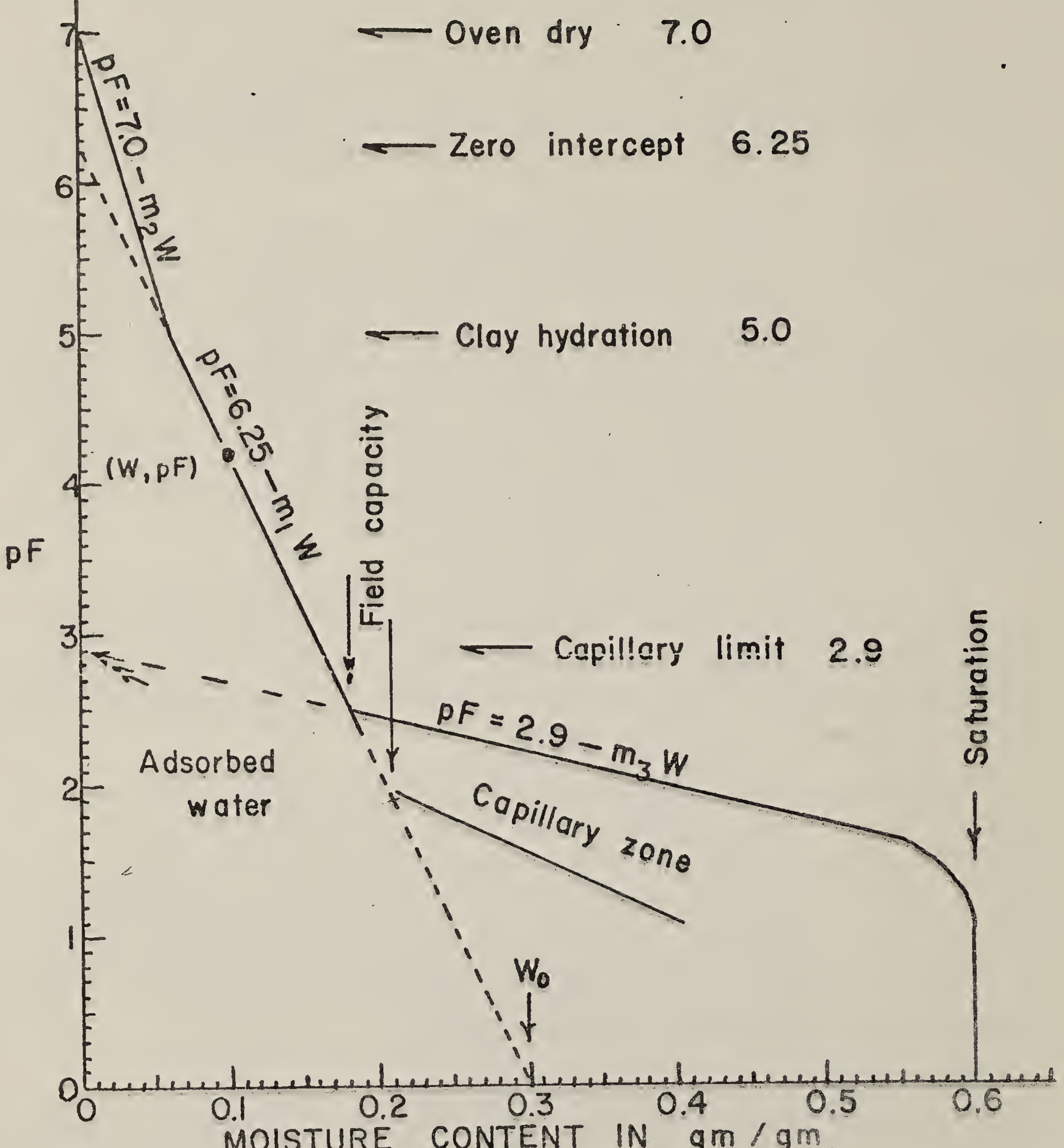


Figure 6.--Definition diagram for method of synthesizing soil moisture characteristic from limited data. In this example the permanent wilting percentage was reported as 10 and sautration percentage as 60. (McQueen and Miller, 1974).

Soil Sampling Procedure and Data Presentation

Soil profiles were sampled at locations indicated on the vegetation map shown on plate 6. Samples were obtained for each 10 cm depth increment, examined in the field to define tentative horizon depths and then sealed for transportation to the laboratory. A moisture-stress sensor (filter paper) was included in each sample.

Vegetation at each sampling site was identified, measured and photographed to define plant community associations. Photographs of the sites and the associated average soil-moisture characteristics are shown on plate 7.

The data are presented in table 24. Definitions and methods for items reported are as follows:

H=Soil Horizon defined hydrologically and determined during field examination but adjusted where bulk density, electrical conductivity, pH or root data indicated a change should be made.

1=That portion of the soil profile that is wetted by capillary or gravity flow during recharge events. The A horizon or leached zone.

2=That portion of the soil profile that receives moisture after recharge events by displacement of the moisture in the 1 horizon. Moisture movement is usually in the form of film flow. A zone of accumulation of clay and salts. Usually corresponds to the B horizon.

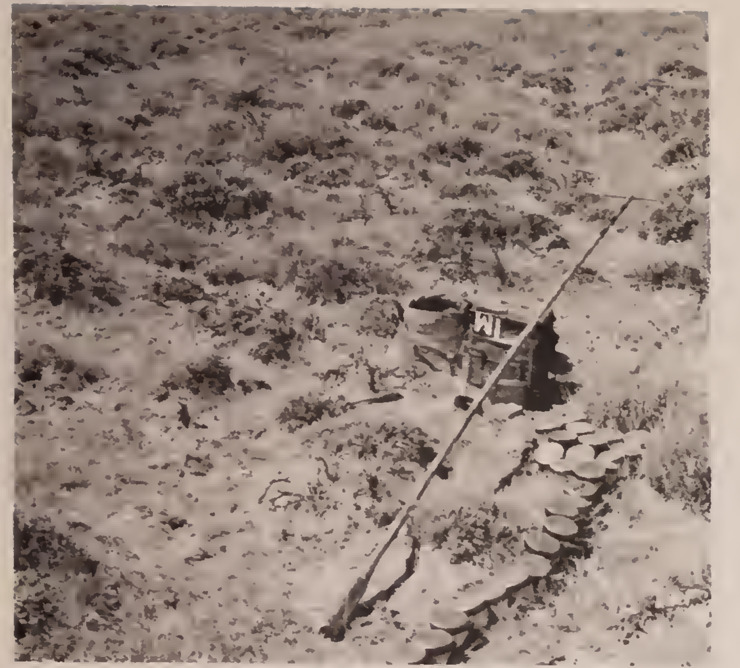
3=That portion of the soil profile that normally receives moisture in the vapor phase. A zone of minimal moisture change. May coincide with the B-2 horizon.

4=That portion of the soil profile with no evidence of live roots indicating that available moisture is seldom used. This usually represents the top of the C horizon.

DPTH=Sampling depth in centimetres. The depth reported is the depth in centimetres to the bottom of the sample.

SM=Soil Moisture or moisture content of the sample in grams of water per gram of dry soil.

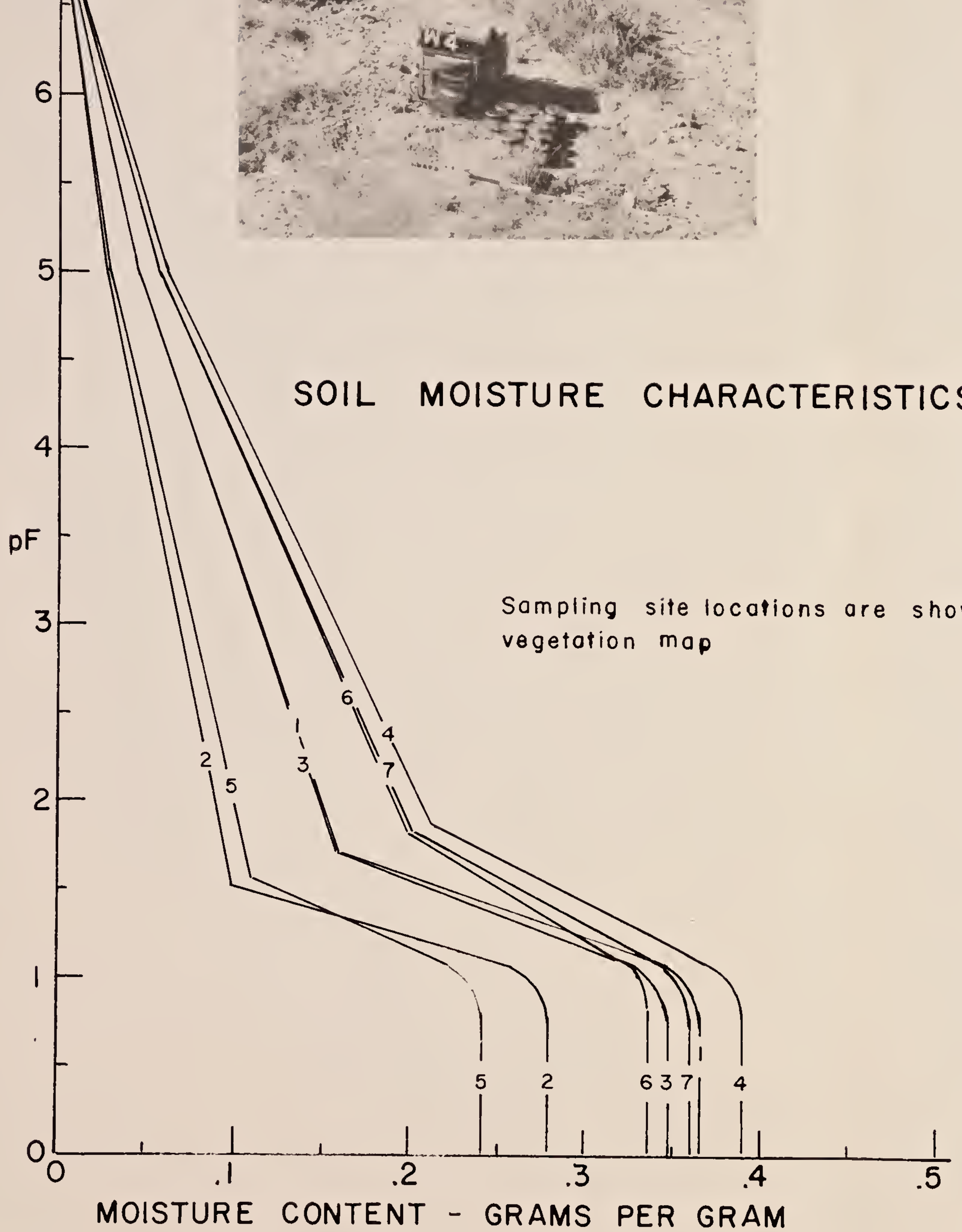
VOL WT=Bulk density or apparent volume-weight in grams



1. Big sagebrush
Western wheatgrass

2. Spiny hopsage

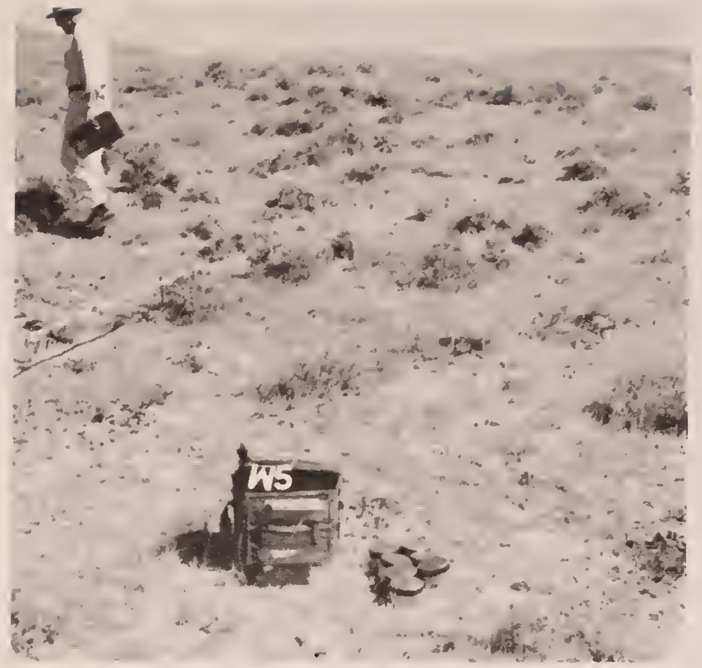
3. Birdfoot sage
Western wheatgrass
Sandberg bluegrass



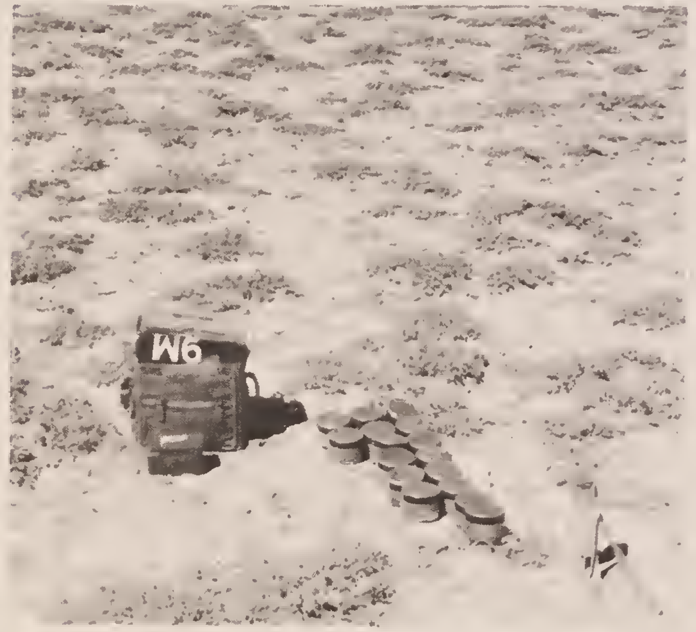
SOIL MOISTURE CHARACTERISTICS

Sampling site locations are shown on the vegetation map

4. Big sagebrush
Shadscale
Rabbitbrush
Western wheatgrass
Bluebunch wheatgrass



5. Big sagebrush
Shadscale



6. Nuttall saltbush

7. Greasewood

Plate 7

Table 24.--Hydrologic data for soils on the Hanna Basin Coal Field Study Site near Hanna, Wyoming

WYM SITE 1 DATE: 9/ 7/74 SAMPLE NO. 1 VEGETATION TYPE: Big sagebrush - western wheatgrass

DEPTH	SM	VOL WT	VOL AVE	FVR	VMC	SMC	TVR	G/CC	SVR	PF	AMC	CMC	LS	EC	PH	ROOTS	ET	TRAN	EK	IR
10	0.0355	1.07	0.0	1.479	.558	.301	0.799	1.70	1.029	5.47	.285	0.017	.027	0.368	6.18	15.00	132.	.811	0.472	0.354
20	0.0664	1.46	1.26	1.098	.415	.402	1.066	1.70	1.186	4.70	.268	0.135	.040	0.547	7.00	10.00	86.	.787	0.517	0.677
30	0.0681	1.49	1.34	0.982	.371	.382	1.012	1.68	1.180	4.53	.247	0.135	.040	0.410	7.43	8.00	95.	.797	0.506	0.584
40	0.0559	1.54	1.50	0.772	.291	.333	0.882	1.71	1.065	4.54	.205	0.128	.033	0.360	7.70	6.00	114.	.821	0.486	0.447
50	0.0455	1.50	1.51	0.757	.286	.299	0.794	1.76	0.957	4.40	.154	0.145	.033	0.321	7.87	5.00	2.	.789		
60	0.0419	1.52	1.52	0.743	.281	.285	0.756	1.78	0.914	4.47	.147	0.138	.033	0.323	8.11	6.00	46.	.854	0.601	1.025
1 AVE	0.0522	1.43		0.972		.334		1.72		4.68	.218		.034	0.388	7.38			.810	0.516	0.617
70	0.0420	1.41	1.48	0.797	.301	.296	0.783	1.78	0.929	4.52	.152	0.144	.027	0.353	8.15	3.00	39.	.723	0.629	1.242
80	0.0417	1.60	1.51	0.756	.285	.285	0.755	1.80	0.891	4.43	.144	0.141	.027	0.407	8.35	4.00	35.	.734	0.648	1.361
90	0.0397	1.80	1.60	0.653	.246	.248	0.658	1.82	0.818	4.48	.141	0.108	.020	0.377	8.46	3.00	26.	.765	0.707	1.662
100	0.0411	1.73	1.71	0.550	.207	.255	0.676	1.82	0.827	4.39	.138	0.117	.027	0.379	7.75	3.00	21.	.740	0.756	2.102
2 AVE	0.0411	1.63		0.689		.271		1.80		4.45	.143		.025	0.379	8.18			.741	0.685	1.592
110	0.0428	2.08	1.87	0.418	.158	.262	0.695	1.82	0.838	4.43	.147	0.115	.027	0.495	8.20	2.00	43.	.693	0.612	1.049
120	0.0421	1.52	1.78	0.492	.186	.273	0.725	1.84	0.834	4.45	.146	0.127	.020	0.543	8.38	2.00	15.	.669	0.850	3.143
130	0.0574	1.81	1.80	0.471	.178	.333	0.883	1.76	1.008	4.34	.188	0.145	.080	1.142	8.39	2.00	46.	.768	0.601	1.142
140	0.0898	2.61	1.98	0.339	.128	.432	1.144	1.66	1.286	4.15	.268	0.164	.080	4.032	7.70	2.00	61.	.905	0.560	0.969
150	0.0961	1.61	2.01	0.319	.121	.442	1.172	1.64	1.330	3.96	.263	0.179	.067	4.098	7.50	2.00	43.	.939	0.612	1.395
160	0.0990	1.80	2.01	0.321	.121	.505	1.339	1.59	1.509	4.12	.290	0.215	.087	4.310	7.57	1.00	56.	.940	0.572	1.134
170	0.0857	2.01	1.81	0.465	.176	.428	1.134	1.63	1.321	4.09	.248	0.180	.087	4.032	7.55	1.00	40.	.919	0.624	1.452
180	0.0827	2.08	1.96	0.350	.132	.426	1.129	1.66	1.276	4.31	.267	0.159	.087	4.032	7.47	1.00	58.	.903	0.567	1.016
190	0.0809	2.10	2.06	0.285	.107	.421	1.115	1.66	1.268	4.37	.269	0.152	.107	3.472	7.45	2.00	58.	.896	0.567	1.008
200	0.0761	2.16	2.11	0.254	.096	.367	0.974	1.73	1.095	4.16	.227	0.140	.080	3.333	7.40	3.00	35.	.863	0.648	1.580
210	0.0776	2.18	2.15	0.234	.088	.393	1.042	1.70	1.172	4.49	.276	0.117	.087	3.378	7.40	2.00	41.	.921	0.620	1.392
220	0.0826	2.25	2.20	0.206	.078	.451	1.196	1.64	1.345	4.48	.292	0.159	.107	2.874	7.36	1.00	58.	.925	0.567	1.043
230	0.0808	2.12	2.18	0.214	.081	.464	1.230	1.61	1.410	4.44	.279	0.185	.087	3.049	7.30	1.00	52.	.935	0.583	1.165
250	0.0763	2.18	2.18	0.214	.081	.392	1.038	1.71	1.157	4.38	.255	0.137	.093	2.688	7.33	1.00	9.	.903	1.048	6.359
260	0.0623	2.36	2.22	0.193	.073	.402	1.065	1.75	1.123	4.40	.211	0.191	.067	2.475	7.32	1.00	39.	.962	0.629	1.528
280	0.0682	2.41	2.32	0.144	.054	.393	1.041	1.65	1.237	4.43	.234	0.158	.093	2.604	7.30	1.00	30.	.937	0.677	1.838
3 AVE	0.0750	2.08		0.307		.399		1.69		4.31	.241		.078	2.910	7.61			.880	0.646	1.701
PROFILE AVE	0.0645	1.86		0.520		.364		1.72		4.42	.221		.060	1.939	7.64			.842	0.730	2.341

Table 24.--Continued

WYM SITE 2 DATE: 9/ 7/74 SAMPLE NO. 1 VEGETATION TYPE: Spiny hopsage

DEPTH	SM	VOL WT	VOL AVE	FVR	VMC	SMC	TVR	G/CC	SVR	PF	AMC	CMC	LS	EC	PH	ROOTS	ET	TRAN	EK	IR
10	0.0112	1.54	0.0	0.718	.271	.270	0.715	1.78	0.891	5.65	.118	0.152	.007	0.238	6.95	30.00	14.	.926	0.873	3.226
20	0.0195	1.14	1.34	0.975	.368	.280	0.743	1.79	0.895	4.82	.085	0.195	.007	0.172	6.79	10.00	13.	.901	0.898	3.579
30	0.0174	1.25	1.31	1.023	.386	.289	0.766	1.81	0.887	5.07	.093	0.196	.007	0.155	6.78	7.00	8.	.858	1.107	6.036
1 AVE	0.0160	1.31		0.905		.280		1.79		5.18	.099		.007	0.189	6.84			.895	0.959	4.280
40	0.0265	2.04	1.48	0.793	.299	.303	0.803	1.80	0.918	4.69	.107	0.196	.013	0.227	6.58	10.00	18.	.908	0.797	2.774
50	0.0227	1.76	1.68	0.574	.217	.271	0.719	1.80	0.872	4.60	.086	0.185	.013	0.159	6.82	0.0	70.	.891	0.542	0.655
60	0.0206	1.48	1.76	0.504	.190	.261	0.691	1.79	0.867	4.58	.077	0.183	.013	0.140	6.83	3.00	7.	.834	1.183	6.309
70	0.0210	1.93	1.72	0.539	.203	.248	0.657	1.82	0.817	4.58	.079	0.169	.007	0.130	6.92	3.00	8.	.741	1.107	5.398
80	0.0208	1.47	1.63	0.630	.238	.254	0.673	1.83	0.816	4.43	.072	0.182	.007	0.131	7.03	2.00	5.	.704	1.431	8.832
90	0.0206	1.61	1.67	0.590	.223	.259	0.687	1.82	0.833	4.44	.071	0.188	.007	0.139	7.08	2.00	7.	.599	1.183	6.388
100	0.0236	1.55	1.54	0.721	.272	.257	0.682	1.80	0.851	4.42	.081	0.176	.007	0.169	7.14	2.00	10.	.726	1.000	4.394
2 AVE	0.0223	1.69		0.622		.265		1.81		4.53	.082		.010	0.157	6.91			.786	1.035	4.964
110	0.0315	1.69	1.61	0.642	.242	.293	0.777	1.79	0.914	4.53	.115	0.178	.013	0.205	6.85	2.00	18.	.784	0.797	2.691
120	0.0495	1.73	1.66	0.599	.226	.275	0.728	1.76	0.919	4.49	.176	0.098	.027	0.312	6.92	2.00	25.	.844	0.715	1.810
130	0.0516	1.88	1.77	0.497	.188	.293	0.777	1.76	0.947	4.65	.202	0.092	.033	0.397	7.03	3.00	23.	.830	0.734	2.071
140	0.0588	1.80	1.81	0.468	.177	.313	0.829	1.75	0.988	4.58	.220	0.093	.033	0.489	7.20	6.00	27.	.805	0.699	1.844
150	0.0700	1.73	1.80	0.470	.177	.355	0.940	1.73	1.075	4.58	.263	0.092	.060	0.594	7.33	5.00	47.	.854	0.598	1.150
160	0.0534	1.96	1.83	0.451	.170	.300	0.796	1.75	0.969	4.55	.196	0.104	.027	0.531	7.65	4.00	29.	.743	0.684	1.663
170	0.0411	2.04	1.91	0.388	.146	.236	0.627	1.84	0.781	4.45	.142	0.094	.013	0.592	7.82	3.00	22.	.585	0.745	1.909
180	0.0379	2.11	2.04	0.302	.114	.215	0.571	1.90	0.695	4.46	.132	0.083	.013	0.774	7.86	2.00	26.	.581	0.707	1.546
190	0.0346	1.91	2.02	0.312	.118	.237	0.628	1.83	0.791	4.42	.118	0.119	.007	0.933	7.88	3.00	13.	.613	0.898	3.221
200	0.0432	1.60	1.87	0.416	.157	.294	0.779	1.74	0.971	4.44	.149	0.145	.027	1.282	8.10	3.00	45.	.734	0.605	1.049
210	0.0545	1.48	1.66	0.595	.224	.356	0.945	1.68	1.140	4.46	.191	0.166	.033	1.678	8.30	4.00	36.	.743	0.643	1.464
3 AVE	0.0478	1.81		0.467		.288		1.78		4.51	.173		.026	0.708	7.54			.738	0.711	1.856
PROFILE AVE	0.0348	1.70		0.581		.279		1.79		4.61	.132		.018	0.450	7.23			.776	0.854	3.238

Table 24 .--Continued

WYM SITE 3 DATE: 9/ 7/74 SAMPLE NO. 1 VEGETATION TYPE: Birdfoot sagebrush-western wheatgrass-Sandberg bluegrass

H	DEPTH	SM	VOL WT	VOL AVE	FVR	VMC	SMC	TVR	G/CC	SVR	PF	AMC	CMC	LS	EC	PH	ROOTS	ET	TRAN	EK	IR
	10	0.0276	1.39	0.0	0.900	.340	.302	0.800	1.82	0.895	5.38	.198	0.104	.020	0.318	6.49	25.00	22.	.560	0.745	2.286
	20	0.0734	1.54	1.47	0.806	.304	.378	1.001	1.70	1.148	4.78	.313	0.065	.060	0.617	6.67	10.00	45.	.744	0.605	1.237
	30	0.0751	1.60	1.51	0.752	.284	.394	1.045	1.70	1.173	4.58	.282	0.113	.060	0.543	7.18	12.00	60.	.754	0.562	0.955
1	AVE	0.0587	1.51		0.819		.358		1.74		4.91	.264		.047	0.493	6.78			.719	0.637	1.493
	40	0.0510	1.84	1.66	0.596	.225	.321	0.850	1.74	1.012	4.49	.181	0.139	.027	0.395	7.60	13.00	96.	.753	0.504	0.525
	50	0.0420	1.71	1.72	0.545	.206	.273	0.724	1.84	0.834	4.52	.152	0.121	.020	0.350	7.87	8.00	67.	.699	0.548	0.703
	60	0.0472	1.55	1.70	0.562	.212	.294	0.780	1.81	0.895	4.47	.166	0.128	.047	0.459	8.06	9.00	45.	.796	0.605	1.091
	70	0.0613	1.51	1.59	0.671	.253	.613	1.623	1.78	1.401	4.44	.212	0.400	.060	0.617	8.17	7.00	99.	.859	0.501	0.815
	80	0.0643	1.54	1.53	0.733	.276	.301	0.799	1.79	0.927	4.49	.229	0.072	.067	0.825	8.28	5.00	304.	.830	0.403	0.163
	90	0.0682	1.68	1.57	0.685	.258	.329	0.873	1.81	0.946	4.44	.235	0.094	.073	1.250	8.23	7.00	943.	.897	0.336	0.057
2	AVE	0.0557	1.63		0.632		.355		1.79		4.48	.196		.049	0.649	8.03			.806	0.483	0.559
	100	0.0920	1.64	1.62	0.640	.241	.412	1.091	1.72	1.175	4.33	.299	0.113	.100	3.378	7.60	3.00	62.	.882	0.558	0.966
	110	0.0798	1.74	1.68	0.574	.217	.391	1.037	1.70	1.169	4.21	.244	0.147	.093	2.907	7.61	2.00	75.	.869	0.533	0.761
	120	0.0652	1.73	1.70	0.557	.210	.288	0.763	1.86	0.835	4.18	.197	0.090	.060	2.404	7.73	4.00	101.	.815	0.499	0.491
	130	0.0725	1.72	1.73	0.533	.201	.346	0.916	1.75	1.038	4.37	.241	0.104	.093	2.577	7.69	3.00	163.	.882	0.452	0.329
	140	0.0548	2.13	1.86	0.426	.161	.318	0.844	1.79	0.952	4.49	.195	0.124	.053	3.165	7.43	6.00	55.	.877	0.575	0.937
	150	0.0397	2.59	2.14	0.237	.089	.238	0.631	1.93	0.700	4.61	.151	0.087	.013	2.049	7.49	2.00	21.	.643	0.756	2.104
3	AVE	0.0673	1.92		0.495		.332		1.79		4.36	.221		.069	2.747	7.59			.828	0.562	0.931
PROFILE	AVE	0.0609	1.73		0.614		.347		1.78		4.52	.220		.056	1.457	7.61			.797	0.545	0.895

Table 24.--Continued

WYM SITE 4 DATE: 9/ 7/74 SAMPLE NO. 1 VEGETATION TYPE: Breaks-Big sagebrush, shadscale, rabbitbrush, western wheatgrass, bluebunch wheatgrass

DEPTH	SM	VOL WT	VOL AVE	FVR	VMC	SMC	TVR	G/CC	SVR	PF	AMC	CMC	LS	EC	PH	ROOTS	ET	TRAN	EK	IR
10	0.0286	0.97	0.0	1.740	.657	.255	0.676	1.83	0.817	5.10	.156	0.099	.040	0.355	7.52	12.00	146.	.568	0.462	0.300
20	0.0439	1.39	1.18	1.244	.469	.281	0.743	1.80	0.885	5.12	.244	0.036	.047	0.417	7.61	10.00	142.	.585	0.465	0.331
1 AVE	0.0362	1.18		1.492		.268		1.81		5.11	.200		.043	0.386	7.56			.577	0.463	0.316
30	0.0661	1.91	1.42	0.860	.325	.332	0.879	1.71	1.064	4.84	.294	0.037	.067	0.598	7.59	5.00	206.	.747	0.432	0.247
40	0.0931	1.56	1.62	0.633	.239	.415	1.099	1.61	1.328	4.66	.370	0.044	.080	1.667	6.45	15.00	410.	.565	0.383	0.137
50	0.0830	1.41	1.63	0.626	.236	.406	1.075	1.62	1.299	4.63	.320	0.085	.073	2.451	7.15	17.00	149.	.888	0.460	0.375
2 AVE	0.0807	1.63		0.706		.384		1.65		4.72	.328		.073	1.572	7.06			.767	0.425	0.253
60	0.0827	1.71	1.56	0.695	.262	.400	1.059	1.66	1.235	4.57	.309	0.091	.073	1.412	7.72	8.00	135.	.916	0.469	0.419
70	0.0898	1.70	1.61	0.646	.244	.449	1.189	1.62	1.370	4.50	.321	0.128	.093	1.309	8.02	6.00	112.	.873	0.488	0.534
80	0.0925	1.86	1.76	0.507	.191	.371	0.982	1.67	1.175	4.40	.313	0.058	.080	1.121	8.11	4.00	113.	.905	0.487	0.476
90	0.0899	2.40	1.99	0.332	.125	.377	1.000	1.71	1.134	4.33	.293	0.084	.080	1.136	8.10	3.00	166.	.908	0.450	0.335
100	0.1028	1.74	2.00	0.324	.122	.473	1.254	1.60	1.440	4.19	.313	0.161	.107	1.445	8.23	2.00	217.	.932	0.428	0.282
105	0.1174	1.77	1.97	0.346	.130	.526	1.394	1.56	1.592	4.22	.362	0.164	.120	1.497	8.23	1.00	143.	.782	0.464	0.447
3 AVE	0.0958	1.86		0.475		.433		1.64		4.37	.318		.092	1.320	8.07			.886	0.464	0.416
PROFILE AVE	0.0809	1.68		0.723		.389		1.67		4.60	.300		.078	1.219	7.70			.815	0.454	0.353

Table 24.--Continued

WYM SITE 5 DATE: 9/ 7/74 SAMPLE NO. 1 VEGETATION TYPE: Big sagebrush-Shadscale

DEPTH	SM	VOL WT	VOL AVE	FVR	VMC	SMC	TVR	G/CC	SVR	PF	AMC	CMC	LS	EC	PH	ROOTS	ET	TRAN	EK	IR
10	0.0178	1.25	0.0	1.124	.424	.261	0.693	1.80	0.857	5.22	.108	0.153	.013	0.226	7.63	8.00	23.	.783	0.734	1.929
20	0.0268	1.48	1.36	0.946	.357	.231	0.612	1.85	0.763	4.82	.117	0.113	.013	0.227	7.50	10.00	48.	.746	0.595	0.861
1 AVE	0.0223	1.36		1.035		.246		1.82		5.02	.113		.013	0.227	7.61			.764	0.665	1.395
30	0.0389	2.26	1.66	0.597	.225	.264	0.699	1.86	0.801	4.79	.167	0.097	.013	0.284	7.58	5.00	135.	.646	0.469	0.343
40	0.0359	1.81	1.85	0.434	.164	.248	0.658	1.85	0.788	4.72	.147	0.102	.013	0.260	7.99	5.00	131.	.619	0.472	0.335
50	0.0373	1.50	1.86	0.428	.162	.227	0.602	1.83	0.777	4.54	.137	0.090	.013	0.245	7.67	3.00	122.	.604	0.479	0.331
60	0.0415	2.14	1.82	0.459	.173	.244	0.646	1.84	0.792	4.57	.155	0.089	.020	0.278	7.83	3.00	115.	.679	0.485	0.374
70	0.0543	1.81	1.81	0.461	.174	.214	0.558	1.99	0.617	4.29	.173	0.041	.020	0.347	8.00	2.00	88.	.501	0.514	0.476
2 AVE	0.0416	1.90		0.476		.240		1.87		4.58	.156		.016	0.283	7.81			.610	0.484	0.372
PROFILE AVE	0.0361	1.75		0.636		.241		1.86		4.71	.144		.015	0.267	7.76			.654	0.536	0.664

Table 24.--Continued

WYM SITE 6 DATE: 9/ 7/74 SAMPLE NO. 1 VEGETATION TYPE: Nuttall saltbush

DEPTH	SM	VOL WT	VOL AVE	FVR	VMC	SMC	TVR	G/CC	SVR	PF	AMC	CMC	LS	EC	PH	ROOTS	ET	TRAN	EK	IR
10	0.0487	0.59	0.0	3.506	****	.384	1.018	1.63	1.250	5.37	.347	0.037	.053	0.575	7.68	9.00	76.	.958	0.532	0.691
20	0.0596	1.70	1.14	1.320	.498	.373	0.988	1.62	1.245	5.24	.370	0.003	.060	0.731	7.47	2.24	195.	.919	0.437	0.269
1 AVE	0.0541	1.14		2.413		.379		1.62		5.31	.359		.057	0.653	7.57			.938	0.484	0.480
30	0.0754	1.69	1.32	1.001	.378	.368	0.974	1.66	1.183	4.76	.316	0.052	.060	0.633	7.52	*****	61.	.909	0.560	0.873
40	0.0809	1.63	1.67	0.586	.221	.393	1.042	1.69	1.184	4.70	.326	0.067	.060	0.672	7.43	6.00	38.	.839	0.633	1.498
50	0.0856	1.50	1.61	0.650	.245	.389	1.030	1.70	1.165	4.64	.332	0.057	.073	0.753	7.49	7.00	56.	.849	0.572	1.014
60	0.0820	1.61	1.58	0.679	.256	.375	0.995	1.68	1.170	4.68	.327	0.049	.060	0.772	7.48	4.00	57.	.736	0.570	0.961
70	0.0703	1.65	1.59	0.672	.253	.313	0.829	1.72	1.023	4.72	.287	0.026	.053	0.708	7.51	5.00	65.	.809	0.552	0.753
80	0.0672	1.73	1.66	0.593	.224	.330	0.874	1.77	0.991	4.70	.272	0.058	.047	0.641	7.57	4.00	57.	.752	0.570	0.919
2 AVE	0.0769	1.63		0.697		.361		1.70		4.70	.310		.059	0.696	7.50			.816	0.576	1.003
90	0.0624	1.48	1.62	0.635	.240	.295	0.781	1.74	0.972	4.72	.255	0.040	.047	0.575	7.48	2.00	84.	.700	0.520	0.563
100	0.0523	1.68	1.63	0.625	.236	.271	0.719	1.85	0.821	4.69	.209	0.062	.040	0.495	7.49	2.00	65.	.551	0.552	0.725
110	0.0482	1.62	1.59	0.664	.251	.235	0.623	1.82	0.798	4.27	.152	0.083	.033	0.439	7.43	2.00	50.	.533	0.589	0.827
120	0.0704	1.80	1.70	0.559	.211	.320	0.848	1.80	0.943	4.77	.299	0.021	.053	0.625	7.43	2.00	56.	.588	0.572	0.930
130	0.0710	1.60	1.67	0.584	.221	.346	0.917	1.73	1.062	4.74	.295	0.051	.053	0.625	7.52	1.00	38.	.591	0.633	1.398
140	0.0418	1.71	1.70	0.555	.209	.305	0.808	1.81	0.910	4.67	.165	0.139	.027	0.408	7.57	2.00	92.	.566	0.509	0.549
150	0.0507	1.57	1.63	0.630	.238	.328	0.870	1.78	0.978	4.70	.205	0.123	.040	0.485	7.65	0.0	66.	.821	0.550	0.796
160	0.0822	1.57	1.62	0.638	.241	.362	0.959	1.71	1.1[illegible]0	4.63	.317	0.044	.067	0.853	7.59	0.0	27.	.799	0.699	2.009
3 AVE	0.0599	1.63		0.611		.308		1.78		4.65	.237		.045	0.563	7.53			.594	0.578	0.974
PROFILE AVE	0.0655	1.57		0.869		.337		1.73		4.75	.280		.052	0.624	7.53			.770	0.565	0.923

Table 24.--Continued

WYM SITE 7 DATE: 9/ 7/74 SAMPLE NO. 1 VEGETATION TYPE: Greasewood

DEPTH	SM	VOL WT	VOL AVE	FVR	VMC	SMC	TVR	G/CC	SVR	PF	AMC	CMC	LS	EC	PH	ROOTS	ET	TRAN	EK	IR
10	0.0340	1.25	0.0	1.123	.424	.344	0.911	1.69	1.107	5.28	.220	0.124	.033	0.556	7.64	10.00	103.	.921	0.497	0.500
20	0.0789	1.42	1.33	0.987	.372	.380	1.008	1.60	1.286	4.77	.334	0.046	.080	0.769	7.62	6.10	573.	.917	0.363	0.092
30	0.0786	1.21	1.29	1.050	.396	.352	0.932	1.65	1.171	4.60	.298	0.054	.073	0.672	7.68	3.00	208.	.906	0.431	0.246
1 AVE	0.0638	1.29		1.053		.359		1.65		4.88	.284		.062	0.666	7.65			.915	0.430	0.279
40	0.0805	1.60	1.41	0.879	.332	.351	0.929	1.66	1.156	4.57	.300	0.051	.067	0.700	7.61	2.00	333.	.883	0.396	0.154
50	0.0715	1.58	1.46	0.810	.306	.298	0.791	1.73	0.989	4.47	.252	0.047	.067	0.610	7.65	2.00	230.	.794	0.423	0.206
60	0.0926	2.00	1.73	0.535	.202	.378	1.001	1.68	1.173	4.51	.334	0.044	.100	0.774	7.96	2.00	358.	.936	0.392	0.153
70	0.0610	1.19	1.59	0.667	.252	.290	0.768	1.74	0.965	4.48	.215	0.075	.047	0.727	8.06	4.00	77.	.967	0.530	0.604
80	0.0673	1.49	1.56	0.700	.264	.340	0.900	1.71	1.076	4.33	.220	0.120	.060	1.553	8.05	3.00	78.	.957	0.529	0.663
90	0.0784	1.39	1.36	0.954	.360	.333	0.883	1.68	1.103	4.21	.240	0.093	.060	3.425	8.12	3.00	92.	.947	0.509	0.545
100	0.0892	1.46	1.45	0.832	.314	.372	0.985	1.68	1.164	4.30	.287	0.085	.053	4.386	8.39	3.00	54.	.963	0.577	1.006
110	0.0945	1.88	1.58	0.680	.257	.401	1.063	1.64	1.264	4.14	.280	0.122	.053	4.464	8.71	3.00	50.	.979	0.589	1.119
2 AVE	0.0794	1.57		0.757		.345		1.69		4.38	.266		.063	2.080	8.07			.928	0.493	0.556
120	0.0972	1.27	1.54	0.725	.274	.396	1.050	1.69	1.190	4.27	.307	0.089	.067	4.098	8.71	2.00	57.	.969	0.570	1.004
130	0.0837	2.17	1.77	0.495	.187	.366	0.970	1.67	1.168	3.94	.226	0.140	.047	3.731	8.78	3.00	39.	.893	0.629	1.365
140	0.0664	1.64	1.69	0.565	.213	.271	0.717	1.81	0.860	4.01	.186	0.085	.027	3.125	8.57	2.00	25.	.781	0.715	1.841
150	0.0694	1.94	1.92	0.382	.144	.239	0.632	1.85	0.774	3.77	.175	0.063	.027	2.874	8.53	1.00	43.	.659	0.612	0.989
160	0.0722	1.99	1.86	0.425	.161	.237	0.627	1.84	0.781	3.59	.170	0.067	.020	3.571	8.47	1.00	35.	.730	0.648	1.201
170	0.0811	1.72	1.88	0.407	.154	.263	0.696	1.82	0.838	3.51	.185	0.078	.033	3.425	8.38	1.00	41.	.681	0.620	1.102
180	0.1252	1.52	1.74	0.520	.196	.375	0.995	1.72	1.119	3.81	.320	0.055	.087	4.545	8.25	1.00	245.	.763	0.419	0.229
190	0.1486	1.34	1.52	0.739	.279	.463	1.228	1.66	1.336	4.07	.426	0.038	.107	5.319	8.04	1.00	329.	.815	0.397	0.191
200	0.1085	1.88	1.58	0.680	.256	.319	0.846	1.73	1.021	3.63	.259	0.060	.080	5.000	8.03	1.00	179.	.708	0.444	0.279
210	0.1758	1.53	1.58	0.675	.255	.549	1.456	1.50	1.737	3.76	.441	0.108	.160	6.250	7.85	1.00	313.	.859	0.401	0.202
220	0.2179	1.66	1.69	0.567	.214	.605	1.604	1.51	1.817	3.75	.544	0.061	.160	6.579	7.59	1.00	386.	.899	0.387	0.175
3 AVE	0.1133	1.70		0.562		.371		1.71		3.83	.295		.074	4.411	8.30			.796	0.531	0.780
PROFILE AVE	0.0942	1.60		0.700		.360		1.69		4.17	.283		.068	3.052	8.13			.860	0.503	0.630

per cubic centimetre. Computed as the dry weight of the soil sample in grams divided by the product of the mean cross-sectional area of the augered hole and the sampling depth increment.

VOL(AVE)=Average bulk density or average apparent volume-weight in grams per cubic centimetre, computed as a moving average. Each figure is the average of three consecutive figures in the preceding column: This computing technique reduces the variability introduced when the auger does not retain the same volume of soil even though the depth to which it is driven is precisely controlled.

FVR=Field Void Ratio - The ratio of the volume of voids to the volume of solids. Computed from the average bulk density by assuming that the density of the solids is 2.65 grams per cubic centimetre. The formula is $FVR=d_s/d_B-1$ where d_s=specific gravity of soil particles and d_B=volume weight or bulk density of the soil in situ (Krynine, 1947, p. 45).

VMC=Voids moisture capacity. The weight of water in grams that would fill the voids in a unit volume (1cc) of soil if the soil mass were confined so that the field bulk density is maintained. Computed as: VMC=FVR/2.65 (Krynine, 1947 p. 32).

SMC=Saturation moisture capacity. The maximum moisture that a sample will absorb under free-swell disturbed conditions; the moisture content at ultimate hydration. Richards et al., (1954), method 2 or ASTM (1958) Designation D 426-39.

TVR=Void ratio for completely saturated sample computed as 2.65 SMC (Krynine, 1947 p. 32).

G/cc=Total density of saturated paste. Determined by weighting 100 cubic centimetres of saturated past after tapping the container on a solid surface to remove the larger air bubbles.

SVR=Saturated void ratio. Void ratio of saturated paste computed from SMC and total density of saturated paste. This void ratio includes minute bubbles of air retained in the paste.

pF=The moisture retention force existing in the soil at the time of sampling. Reported is the logarithm of the height of a column of water supported by an equivalent force. PF is measured using the method of McQueen and Miller (1968).

AMC=Adsorbed moisture capacity. This represents the moisture content in grams required to satisfy all of the molecular adsorptive forces exerted by a gram of soil particles. Computed as AMC=-6.25 SM/(pF-6.25). This value is the intercept of the adsorbed segment of the moisture characteristic with the X (or zero pF) axis.

CMC=Capillary moisture capacity. Computed as SMC-AMC. Where this value is negative it means that the soil moisture characteristic probably can have no capillary segment because the pores are too small.

LS-Linear shrinkage. Ratio of the change in diameter of a cylindrical pat of saturated paste during desiccation to the original diameter of the saturated pat.

EC=Electrical conductivity of saturated paste. Richards et al. (1954), method 5 except that a two prong stainless steel probe is used in place of the Bureau of Soils electrode cup.

PH=The negative logarithm of the hydrogen ion concentration in the saturated paste. Richards et al. (1954), method 21a.

ROOTS=Relative concentration of roots.
The material retained on a 60-mesh sieve in a wet sieving process was examined and the relative concentration within the profile was estimated. The concentration of roots in the second sample (10 to 20 cm) was given a value of 10 and the other samples were given relative numbers.

ET=Erosion time (minutes). Time in minutes required to erode the sample after it has been saturated, puddled, placed in a cylindrical container, allowed to air dry, removed from its container and subjected to an erosive force that simulates a flowing stream with a velocity of 0.58 meter per second measured about 2 cm from the eroding surface.

TRAN=The ratio of transportable to total weight of A 60-mesh (0.25 mm) sieve has been arbitrarily chosen to define the boundary between suspended and bedload material. Those particles smaller than 0.25 mm can be suspended in a moderately turbulent stream. Particles larger than 0.25 mm will usually be bedload.

EK=Erodibility constant. Computed as the reciprocal of the logarithm of the erosion time. $EK=1/\log_{10}ET$. This

relationship is discontinuous at ET=1 and because short erosion times are difficult to measure accurately, for samples where ET approached 1 minute, a value of 2 minutes was arbitrarily assigned. Also, when a sample had not disintegrated after 24 hours in the erosion test device it was removed and arbitrarily assigned a time of 24 hours.

Note: EK is similar in form to the K value defined by Wischmeier et al. (1969), for use in the universal soil-loss equation. However, it should not be considered as a replacement or duplication because it is derived from erosion tests instead of grain size data. Parallel tests have not been conducted to define the relationships between EK and K.

IR=Infiltration rate. Computed from the dimensions of the saturated soil pat and the erosion time by assuming that when erosion is complete sufficient water has entered the pat to completely saturate it. When an erosion pat is reinforced with roots or gravel particles in a clay matrix its ET may be extended and the computed IR may be too small. IR, as reported, should be considered as a minimum infiltration rate in cubic centrimetres per square centimetre per hour.

Discussion

An objective of this study was to define the hydrologic characteristics of soils associated with vegetation types existing on sites proposed for surface mining of coal. Many hydrologic properties of soils are not constant but can change on or two orders of magnitude under natural conditions. Greater changes can be expected during the disturbance of mining operations.

One property of a soil that will not change appreciably is its specific surface. This can be changed by weathering or by crushing and grinding but these changes are slow. Hydrologic characteristics that are functions of specific surface can be defined for individual soil samples or for mixtures of soils. The adsorbed film segment of the moisture retention characteristic of a soil is a direct function of the specific surface and can be defined by a single parameter AMC. Evaporation and transpiration can be estimated from the soil moisture characteristics for the soil horizons and a knowledge of the growth patterns and moisture requirements of the plants.

Any hydrologic characteristic that is dependent on the geometry of the pore space will be changed by the disturbance of surface mining. If these characteristics are to be defined they must be defined in terms of the porosity that will exist or some

parameter related to the porosity. The nomograph shown on figure 7 is provided to assist in making estimates of porosity and related functions. This nomograph assumes a two phase system of soil particles and water. Where three phases are present (soil, air and water) appropriate corrections or adjustments should be made to the data or estimates. For example, when the total density is computed from the moisture content of a saturated paste it is usually higher than the measured density because of air bubbles included in the paste. A similar source of error is involved in computation of specific gravity of soil particles from shrinkage limit and shrinkage ratio (ASTM (1958) Designation D426-39, paragraph 10).

Void ratios are used to control compaction of soil in engineering practices. The nomograph is useful in conversions between density data, porosities, void ratios, and saturated moisture contents. This nomograph can be constructed for any particle density.

The forces involved in erosion of soils are extremely complex and variable. Prediction of erosion rates from laboratory tests of physical properties of soils has not be successful. It is possible, however, to define relative susceptibility of soils to a given set of erosion forces by controlled tests (McQueen, 1961). For significant results, the erosion forces and the condition of the samples prior to and during the tests should simulate conditions expected in the field.

Three methods for determining soil erodibility have been combined in a laboratory test for defining the susceptibility of these soils to erosion forces. A slaking test suggested by Winterkorn (1973); rotating cylinder methods; (described by Masch et al., 1965 Akky, and Shen 1973; Arulanandan et al., 1973) and an erodibility factor (described by Wischmeier and others 1958, 1959, 1965, 1969, 1971a, 1971b and 1973)based on measurements of grain size and other physical and chemical properties. This test constitutes a direct determination of the inherent erodibility of individual soil samples.

These data can be averaged and combined to predict the erodibility of the disturbed and mixed soils.

Sample computations

The data from individual samples presented in this report can be combined and averaged in various ways to predict how the soils will perform when mixed by the mining procedure. Data from sampling site Number 1 are used here as an example. Similar computations can be made for other materials that may be available.

The B Horizon of a soil is usually the prime source of

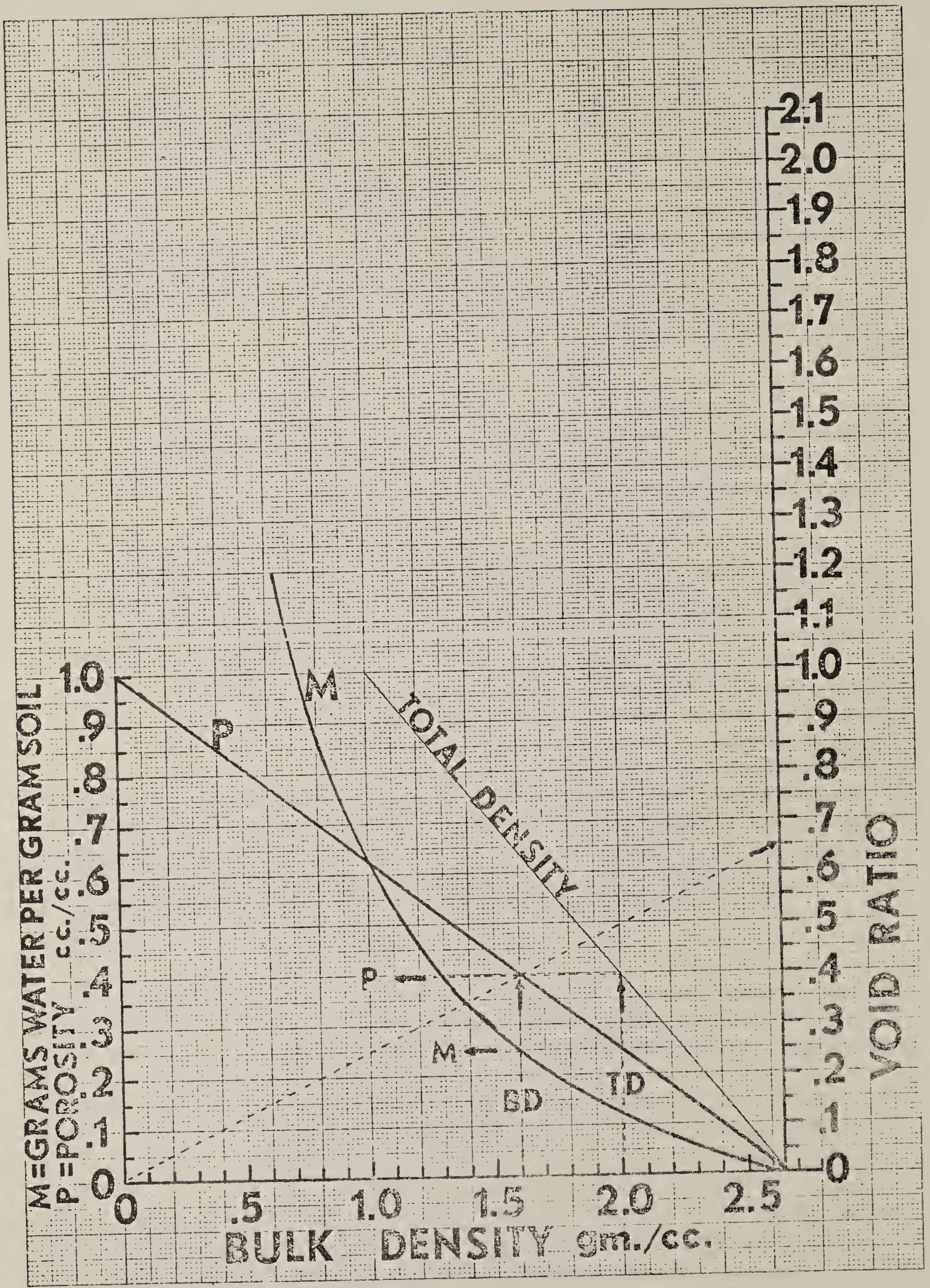


Figure 7.--Nomograph for conversion between bulk densities, total densities, porosities, saturated moisture contents and void ratios.

moisture and nutrients for sustaining plant growth. The average soil moisture characteristic for this horizon at site 1 is illustrated in figure 8. Using the method of McQueen and Miller (1974) the adsorbed segment of the characteristic is drawn between the pF, intercept at (0, 6.25) and the M_o intercept for the mean AMC at (0.1434, 0). The mean SMC value of 0.271 is plotted at pF 0.0 and a short vertical segment is drawn. The capillary segment is drawn from the capillary limit (0, 2.9) through the field capacity value on the adsorbed segment (0.086, 2.5). ΔM=(AMC/pFo(Δ pF)-(0.14/6.25) (6.25-2.5)-0.086. A short transition curve may be drawn between the capillary segment and the SMC line, and the structured water segment may be drawn between the oven-dry intercept at (0, 7.0) and the value of the adsorbed segment at pF 5.0 (0.0287, 5.0). The moisture characteristic for the mixed profile of site 1 is drawn by using the average AMC and SMC values for the complete profile. AMC=0.2208 SMC=0.364 the change in moisture content for a given change in moisture stress in the adsorbed range can be computed from: ΔM=(AMC/6.25)(Δ pF). For example, the available moisture storage is usually assumed to be the change in moisture content between field capacity (pF 2.5) and permanent wilting (pF 4.2). For the B Horizon of site 1 this would be (0.1434/6.25)(4.2-2.5)=0.039 gm/gm or 3.9 percent. With an average bulk density of 1.635 the available storage would be $(\rho_B)(M_w)=M_v$ (1.635)(0.039)=0.0638 cc/cc. Moisture represented by the capillary segment of the characteristic may be utilized only if plant roots reach the capillary fringe or if trickle irrigation is used.

Infiltration is low and erodibility for this site is high so contour furrowing may be used to decrease erosion. Infiltration rates on the mixed soil will probably exceed 1 centimetre per hour. If the contour furrows will retain 4 centimetres of precipitation then a 2-hour storm of 3 centimetres per hour intensity could be retained. This 6 cm storm would recharge 94 centimetres of soil with the storage capacity of the 2(B) Horizon. (6/0.0638=94) or 61 centimetres of the mixed profile [depth recharged=precipitation/ $M.\rho_B$] where: ΔM=(AMC/pFo) ΔpF=(0.22/6.25)(4.2-2.5)=0.0598. Depth recharged=6/(0.0598)(1.635)=61.3.

The volume of pores within a soil may be defined in terms of bulk density, total density, porosity or void ratio. Three void ratios are reported for each sample. FVR (Field Void Ratio) is computed from the average volume weight as: ρ_s/ρ_B [particle density/volume weight]-1 (Krynine 1947, p. 45). The average volume-weight of the B Horizon of site 1 is 1.635 then the void ratio=2.65/1.635-1=0.6208. If this soil is saturated and not restrained so that it is free to swell its theoretical maximum void ratio (TVR) would be the saturated moisture content times the density of soil particles (0.271)(2.65)=0.718 (Krynine 1947,

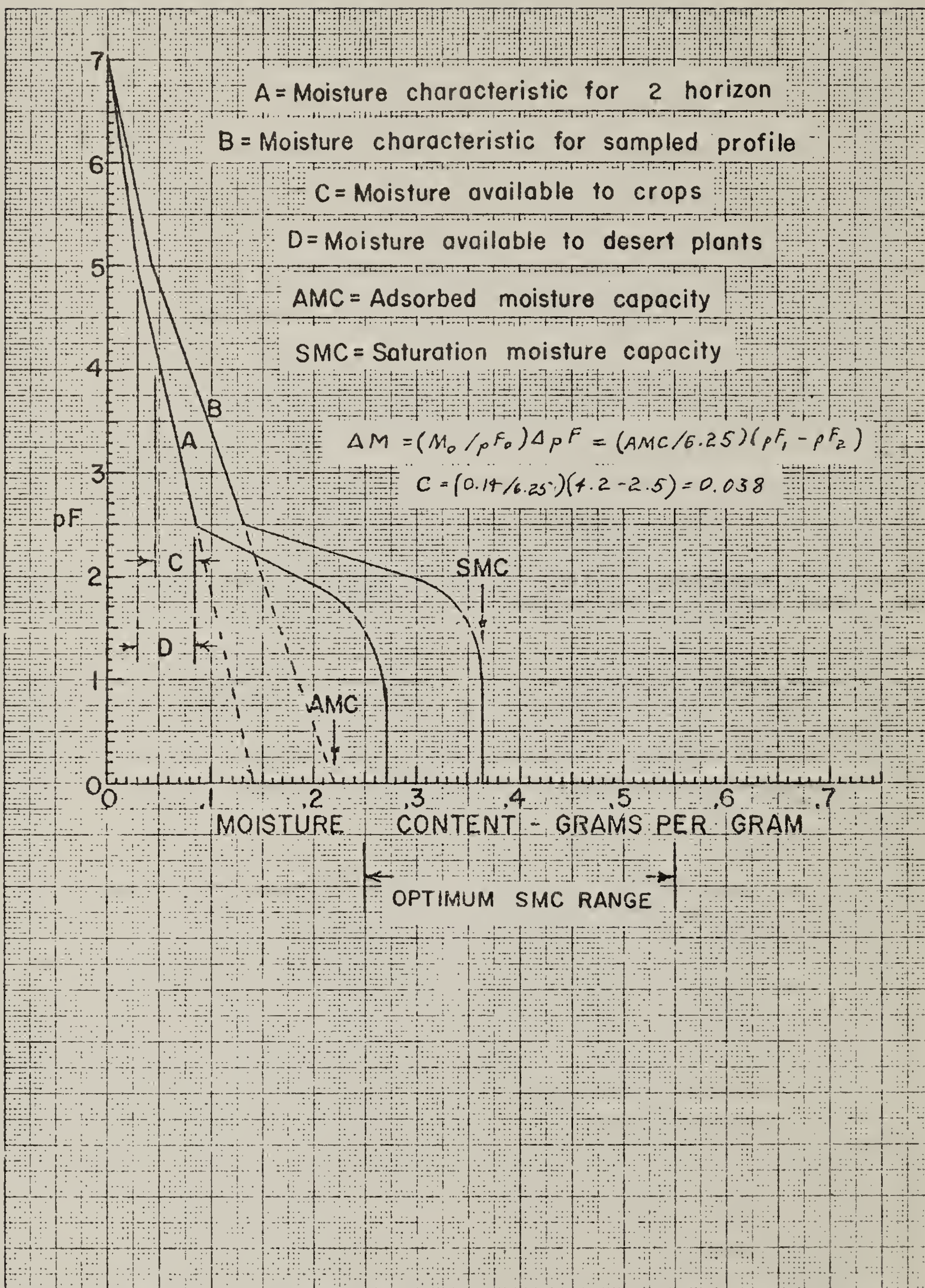


Figure 8.--Soil moisture characteristics for the 2(B) Horizon and the profile for sampling site No. 1.

p. 32). The saturated void ratio (SVR) was also computed from the measured density of the saturated paste, but because saturation is never quite complete the two void ratios are not the same. The difference is a measure of the volume of air bubbles in the saturated paste.

Summary and Inferences from the Data

Selected parameters are summarized by soil horizon and by profile and presented as averages in table 25. On the basis of these data some conclusions and suggestions can be made.

1. The soils of this area have low moisture storage capabilities which indicates that revegetation may be accomplished with arid lands species. Other species may require more frequent recharge than prevailing climate patterns provide.

2. Erodibility of these soils is high so some form of surface treatment such as contour furrowing is suggested to impede runoff and erosion.

3. Mixing of soils from separate soil horizons may be beneficial for revegetation because it usually improves the moisture retention capabilities at the surface where it is needed for seedling establishment.

4. Compaction of these soils as they are replaced may decrease erodibility but it would also decrease infiltration and impede revegetation. Erosion rates may be increased because of higher runoff from compacted soils.

5. Nuttall saltbush and greasewood usually indicate that soils require special surface treatments if revegetation is to be successful. The soils on sites 6 and 7 should either not be used or they should be contour furrowed to provide maximum opportunity for leaching of soluble salts in the profile.

Table 25 Summary of average data for soil horizons and soil profiles on the Hanna Basin Coal Field study area near Hannah, Wyoming

Site	Horizon	Depth cm	$_{p}F$	M	SMC	AMC	ΔM cc/cc	Vol. wt.	M use cm	EK	TR	IR	EC	Nat. cov.	RC	S.T. Req.
1	1	60	4.68	.052	.334	.218	.149	1.43	8.96	.506	.81	0.62	.388	----	2	2
	2	100	4.45	.041	.271	.143	.113	1.63	2.25	.685	.74	1.59	.379	----	1	1
	3	280	4.31	.075	.399	.241	.216	2.08	11.25	.646	.88	1.30	2.910	----	3	2
	Profile	---	4.42	.064	.364	.221	----	1.86	22.46	----	.84	----	1.939	.49	3	2
2	1	30	5.18	.016	.280	.099	.062	1.31	1.86	.959	.90	4.28	.189	----	1	1
	2	100	4.53	.022	.265	.082	.066	1.69	2.32	1.035	.79	4.96	.157	----	1	1
	3	210	4.51	.048	.288	.173	.151	1.81	3.31	.711	.74	1.86	.708	----	2	1
	Profile	---	4.61	.035	.279	.132	----	1.70	7.49	.854	.78	3.24	.450	.63	1	1
3	1	30	4.91	.059	.358	.264	.192	1.51	5.74	.637	.72	1.49	.493	----	3	2
	2	90	4.48	.056	.355	.196	.154	1.63	4.62	.483	.81	.56	.649	----	2	2
	3	150	4.36	.067	.332	.221	.204	1.92	2.45	.562	.83	.93	2.747	----	2	2
	Profile	---	4.52	.061	.347	.220	----	1.73	12.81	.545	.80	.90	1.457	.46	2	2
4	1	20	5.11	.036	.268	.200	.113	1.18	2.27	.463	.68	.32	.386	----	2	2
	2	50	4.72	.081	.384	.328	.226	1.63	3.40	.425	.77	.25	1.572	----	3	3
	3	105	4.37	.096	.433	.318	.251	1.86	3.02	.464	.89	.42	1.320	----	3	3
	Profile	---	4.60	.081	.389	.300	----	1.68	8.69	.454	.82	.35	1.219	.36	3	3
5	1	20	5.02	.022	.246	.113	.074	1.36	1.48	.665	.76	1.40	.227	----	1	2
	2	70	4.58	.042	.240	.156	.142	1.90	3.56	.484	.61	.37	.283	----	1	2
	Profile	---	4.71	.036	.241	.144	----	1.75	5.04	.536	.65	.66	.267	.48	1	2
6	1	20	5.31	.054	.379	.359	.174	1.14	3.48	.484	.94	.48	.653	----	4	3
	2	80	4.70	.077	.361	.310	.223	1.63	6.70	.576	.82	1.00	.696	----	3	3
	3	160	4.65	.060	.308	.237	.186	1.63	2.97	.578	.69	.97	.563	----	2	2
	Profile	---	4.75	.066	.337	.280	----	1.57	13.15	.565	.77	.92	.624	.16	3	3
7	1	30	4.88	.064	.359	.284	.156	1.29	4.67	.430	.92	.28	.666	----	3	2
	2	110	4.38	.079	.345	.266	.177	1.57	7.10	.493	.93	.56	2.080	----	3	2
	3	220	3.83	.113	.371	.295	.212	1.70	4.66	.531	.80	.78	4.411	----	3	2
	Profile	---	4.17	.094	.360	.283	----	1.60	16.43	.503	.86	.63	3.052	.60	3	2

$_{p}F$ = Average moisture stress when sampled

M = Average moisture content when sampled

SMC = Average saturating moisture capacity

AMC = Average adsorbed moisture capacity

ΔM = Moisture use between field capacity and ultimate plant stress as volume ratio

Vol. wt. = Average volume weight

M Use = Computed moisture depletion for horizon. Profile value is the sum of the horizon

EK = Average erodibility constant

TR = Average transportability ratio

IR = Average minimum infiltration rate

EC = Electrical conductivity of saturated paste

Nat. cov. = Natural cover of live vegetation

RC = Revegetation textural classification
- 1 = Coarse soil - requires irrigation
- 2 = Marginal sandy loam soil
- 3 = Optimum soil texture
- 4 = Marginal clay loam soil
- 5 = Clay soils - require surface treatment

S.T. Req. = Surface treatment requirement such as Arcadia contour furrowing
- 1 = Probably no benefit
- 2 = Beneficial for erosion control
- 3 = Required for vegetation establishment

Study site hydrology and water supply

Surface water

Amount and quality

Streams in the immediate vicinity of the Federal coal leases are ephemeral, and most of them flow directly into Seminoe Reservoir. (Refer to appended 7½ minute quadrangle contour maps.) Several streams near the southern end of the study area flow into closed basins and have no apparent outflow. A few springs do exist that cause intermittent flows of a few streams in the general area; however, most of these streams are tributaries of Medicine Bow River, and are east of the study area. Drainage patterns of the area are mainly of a dendritic nature, with courses of the minor tributaries being affected in development by local inequalities in soil and rock resistance.

Streamflow in the vicinity of the study area occurs from both snowmelt and rainfall. The major portion of annual runoff occurs during the months of May, June, and July. Streamflow is highly variable, and some of the smaller streams commonly have periods of a year or more with no flow. When flow does occur, it is often in the form of a flood. Although instantaneous flows of the flood peaks may be high, total runoff amounts are generally small due to the short duration and infrequent nature of the flows.

Concentrations of suspended sediment, and turbidity, generally increase as flow increases; whereas, concentrations of dissolved solids decrease as flow increases.

Sediment load of any stream is dependent upon (1) the ability of the watershed to supply sediment, and (2) the ability of the stream to transport the sediment. Because parts of the study area are highly erodible, an ample supply of sediment exists for transport. High sediment loads occur during high flows when the stream has large amounts of energy available for eroding and transporting sediment. Concentrations of suspended sediment can therefore vary from several milligrams per litre during low flows to over 100,000 milligrams per litre during high flows.

Several photos of the area's streams are shown to illustrate the balance that exists in the stream channels between runoff and sediment. Plate 8 shows a channel that has filled as a result of backwater from a small dam.

Plate 8
Looking downstream at filled-in channel,
tributary of Big Ditch near Hanna.

Plate 9 shows a channel near Hanna that has downcut as a result of two things: (1) an upstream reservoir captures the stream's sediment load, and the relatively clear outflow of the reservoir has the ability to pick up and transport material from the streambed, and (2) dewatering of old coal mines in the Hanna area contributed to accelerated erosion in parts of this channel.

Plate 9
Looking downstream at gully of tributary to Big Ditch near Hanna.

The potential for high erosion of channels is shown by plate 10, which shows headcut of a tributary near Hanna.

Plate 10
Headcut on tributary of Big Ditch near Hanna.

In general, streambeds of the area are composed of fine gravel, sand, silt, and clay; relative proportions of each vary locally depending on soil composition of the watershed. A bed material sample of Big Ditch, taken about 1.0 mile upstream from its mouth, was analyzed for size gradation as shown in figure 9.

The graph shows roughly the type of material that makes up the streambeds of the area's streams. Bed-material size of a particular stream system generally decreases in the downstream direction.

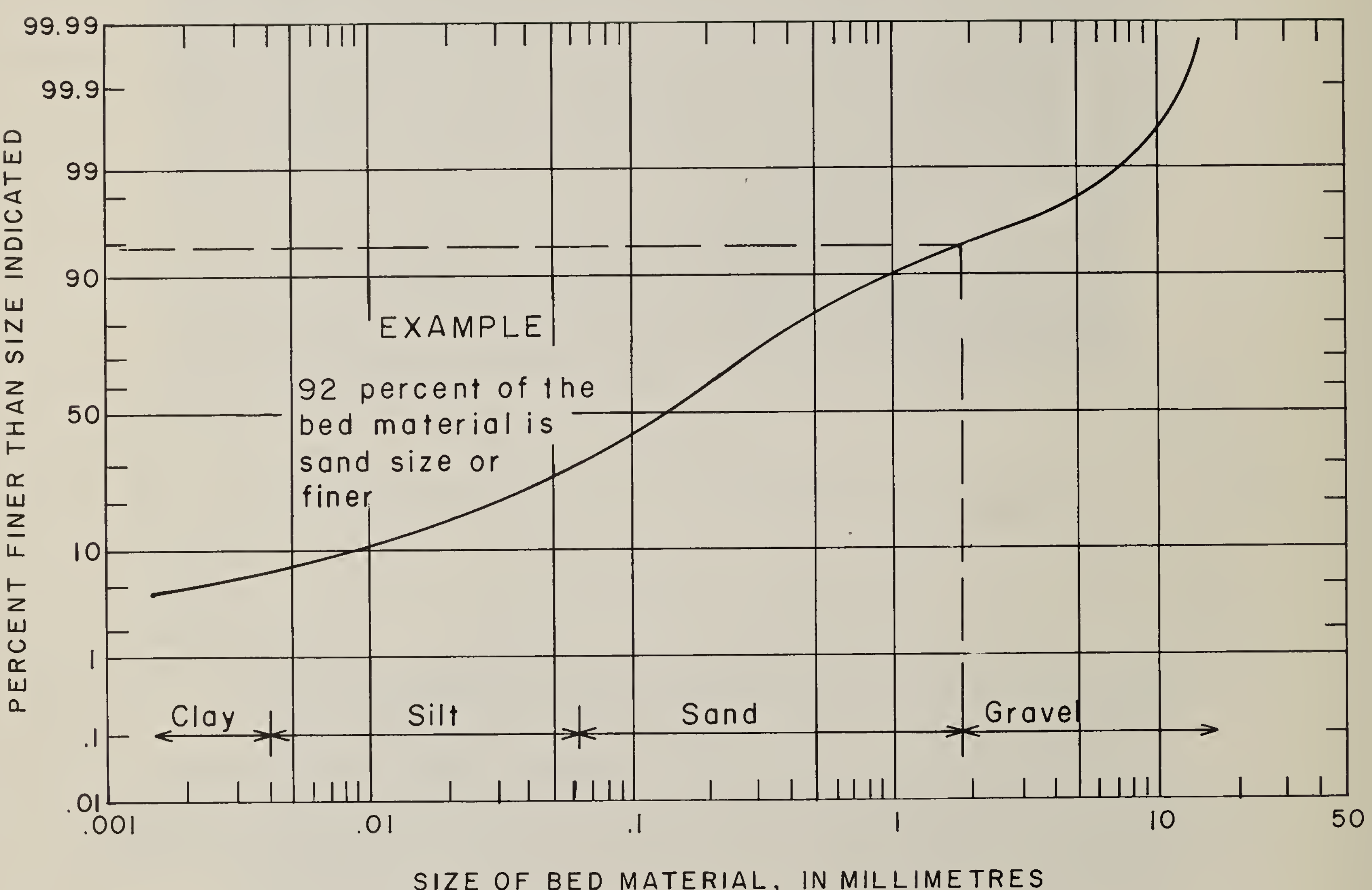


Figure 9.—Size of bed material, Big Ditch near Hanna, Wyoming.

Chemical constituents of stream water are derived primarily from the rocks and soil over and through which the waters of precipitation travel to reach a stream channel. Water dissolves chemical constituents from the soil and rocks. Dissolved-solids concentrations are usually highest during periods of low flow, when water reaches the stream only after a slow journey that often spans considerable distance. Dissolved-solids concentration of the area's streams can be expected to range from about 300 to over 1,000 milligrams per litre, depending on the magnitude and duration of the flow.

A gaging and sampling program has been implemented so that basic hydrologic relations and qualities of the area's streams can be accurately identified and monitored.

Subsurface water

Depth to water

The well numbers used in this report indicate the well location. The numbering system is based on the Federal system of land subdivision. The number shows the location of the well by township, range, section, and position within the section. The first numeral indicates the township, the second the range, and the third the section in which the well is located. Lowercase letters following the section number locate the well within the section. The first letter denotes the quarter section, the second the quarter-quarter section, and the third the quarter-quarter-quarter section. The letters are assigned within the section in a counterclockwise direction beginning with (a) in the northeast quarter of the section. Letters are assigned within each quarter section and quarter-quarter section in the same manner. For example, 23-84-12acb indicates a well in the northwest quarter of the southwest quarter of the northeast quarter of sec. 12, T. 23 N., R. 84 W.

The Bureau of Reclamation drilled eight holes, continuously cored, of which six were cased. In addition to these, four holes drilled by the Medicine Bow Coal Company were cased. Five stock wells and two wells used for water supply for the Medicine Bow Coal Company were also used as data points. Table 26 describes all data points. Figure 10 shows the location of all wells.

Table 26 -Descriptions of wells in the EMRIA study site and adjacent areas, Hanna basin, Wyoming.

Location Township N., Range W., Sec. ¼,¼,¼	Other well number	Altitude of land surface above mean sea level (ft)	Depth of well below land surface (ft)	Diameter of well (in)	Distance to water below land surface (ft) (Dec. 1974)
24-83-30ddd	a/9001	6,620	205	1.5	118.2
24-83-32ddd	a/9006	6,500	97	2	68.2
23-83-6bbb	a/9003	6,435	146	1.5	77.2
23-83-6ddd	a/9004	6,490	200	1.5	51.9
23-84-12cbd	a/9008	6,450	200	2	89.9
23-84-12acb	a/9005	6,425	200	2	51.8
23-83-7cab	---------	6,420	124	6	43.7
23-83-19bbc	b/W.W. 2	6,440	380	6	86.3
23-83-19daa	b/W.W. 5	6,460	503	6	81.3
23-83-21bda	---------	6,496	---	6	44.7
23-83-29cda	b/12646	6,544	171	2	101.9
23-83-31aba	---------	6,433	---	8	52.1
23-83-32acd	b/12880	6,449	200	2	30.0
23-83-32adb	b/12944C	6,477	112	2	42.9
23-83-32ada	b/12950C	6,461	115	4	21.0
23-83-33bca	---------	6,460	---	8	12.0
22-83-5ddb	---------	6,539	---	8	79.8

a/ Bureau of Reclamation number.

b/ Medicine Bow Coal Company number.

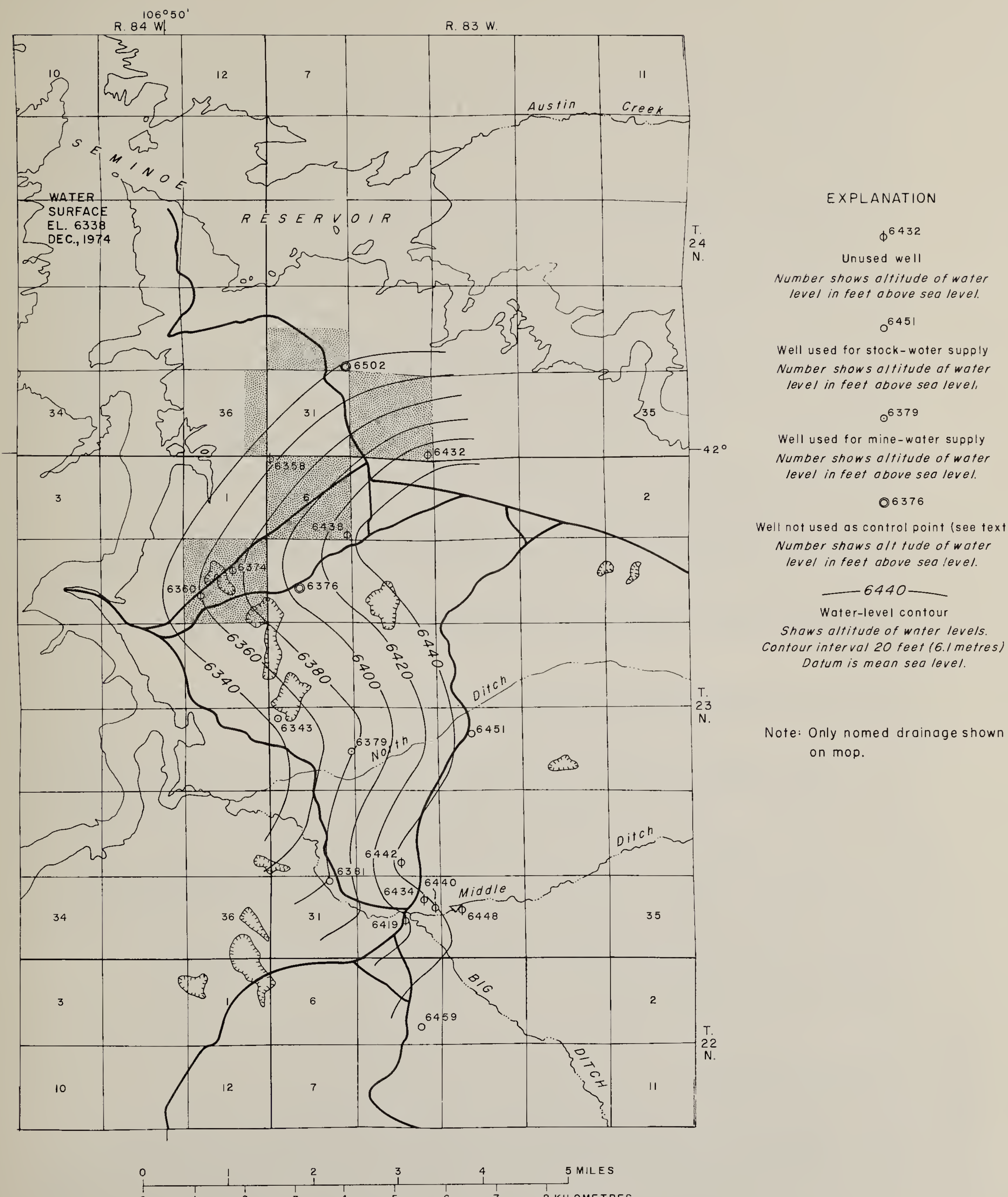


Figure 10.— Location of wells and approximate contours of water level altitudes in the Ferris Formation, northwest Hanna structural basin, Wyoming (December 1974).

Direction and velocity of flow

None of the Bureau of Reclamation holes were open to the same coal beds. From the logs of these holes, it appears that the water-bearing units are principally the coal beds and some sandstones. The jointing identified in the cores, and the silty nature of the sandstones suggest jointing as the principal source of permeability. Some of these saturated beds are confined and some unconfined. Because any one well is open to more than one bed, the water levels in the wells are the result of a combination of more than one potentiometric surface. Figure 10 shows this combined surface. Well 9001 and the stock well in sec. 7, T. 23 N., R. 83 W. were not used as data points for contouring, because from the logs it appeared the water levels were perched above all the others. The gradient of any individual potentiometric surface probably is greater than the gradient of the combined potentiometric surfaces. The flow is toward Seminoe Reservoir. In deeper aquifers, this may reverse, with the reservoir recharging the aquifer. At Big Ditch the gradient is toward the ditch, probably because the alluvium filling the ditch is about 40 feet thick, truncates the aquifers and has greater vertical permeability. Water from the aquifers discharges to the alluvium and flow in Big Ditch is mainly underflow. Faulting in the area affects the water levels and flow but, due to an inadequate number of data points, the effect of each fault was not described.

Results of pump tests performed

No aquifer tests were performed in the specific site area because the small-diameter wells and depth to water made the usual methods impossible. It is planned to case holes drilled by the Medicine Bow Coal Company in the spring of 1975 and conduct a test then. Well 23-83-32ada was pumped, giving a specific capacity of 0.9 gpm/foot after 46 minutes. This supports the expectation of low transmissivity. These data may not apply to the specific site area, due to the effect of faulting and jointing. A pump test should be performed in the planned mining area to evaluate dewatering operations.

Chemical quality

Samples of water from five of the wells drilled by the Bureau of Reclamation were analyzed and the results are shown in Table 27 with EPA recommended standards (1973). These standards are given only as guides for comparison and are not absolutes as they depend on many factors, such as temperature, species of plant being irrigated, and soil type.

Table 27. --Chemical analyses of water from wells in the Hanna-EMRIA area (December 1974)

[Field values used for pH and specific conductance, results in milligrams per liter (mg/l) or micrograms per liter (μg/l), except where indicated.]

	Well number (township, range, section $\frac{1}{4},\frac{1}{4},\frac{1}{4}$)a/, and Bureau of Reclamation number					EPA recommended standards for maximum concentrations of toxic substances b/			
	24N83W30ddd 9001	24N83W32ddd 9006	23N83W06bbb 9003	23N83W06ddd 9004	23N83W12acb 9005	In livestock waters	In waters used continuously on all soil	For use up to 20 years on fine-textured soils of pH 6.0 to 8.5	Public water supplies, ground water
Silica - SiO_2 (mg/l)	21	6.4	23	7.1	20	---------	--------	--------	------------
Iron - Fe (μg/l)	33,000	50	800	130	140	(c)	5,000	20,000	300
total (μg/l	41,000	32,000	23,000	10,000	18,000				
Calcium - Ca (mg/l)	110	33	270	240	110	---------	--------	--------	------------
Magnesium - Mg (mg/l)	170	22	290	250	5.8	---------	--------	--------	------------
Sodium - Na (mg/l)	28	730	160	660	410	---------	--------	--------	(c)
Potassium - K (mg/l)	25	9.8	20	17	5.6	---------	--------	--------	------------
Bicarbonate - HCO_3 (mg/l)	120	1,300	867	975	1,020	---------	(c)	(c)	------------
Carbonate - CO_3 (mg/l)	0	0	0	0	0	---------	--------	--------	------------
Sulfate - SO_4 (mg/l)	950	610	1,400	2,300	28	---------	--------	--------	250
Chloride - Cl (mg/l)	6.5	31	19	16	66	---------	(c)	(c)	(c)
Fluoride - F (mg/l)	.1	.4	.2	.3	.3	2.0	1.0	15.0	1.4-2.4 d/
Total nitrogen as nitrate - NO_3 (mg/l)	71	43	--------	25	22	---------	(c)	(c)	10
Total nitrogen - N (mg/l)	16	9.6	--------	5.5	4.9	---------	--------	--------	------------
Total nitrogen as nitrite and nitrate - NO_2+NO_3 (mg/l)	.05	.00	--------	.04	.09	100	--------	--------	(e)
Total nitrogen as ammonia - NH_4 (mg/l)	16	3.5	8.8	6.0	1.7	---------	--------	--------	.5
Total Kjeldahl nitrogen (mg/l)	16	9.6	5.7	5.5	4.8	---------	--------	--------	------------
Total organic nitrogen (mg/l)	.0	6.1	.0	.0	3.1	---------	--------	--------	------------
Total phosphorus - P (mg/l)	.59	.54	.50	.13	.72	---------	--------	--------	(c)
Dissolved solids (sum of constituents) (mg/l)	1,410	2,080	2,610	3,970	1,150	---------	(f)	(f)	(f)
Hardness - Ca, Mg (mg/l)	970	170	1,900	1,600	300	---------	--------	--------	(c)
Noncarbonate hardness (mg/l)	880	0	1,200	830	0	---------	--------	--------	------------
Alkalinity, total as $CaCO_3$ (mg/l)	98	1,070	711	800	837	---------	--------	--------	(c)
Specific conductance (micromhos)	1,980	2,810	3,100	4,350	1,550	---------	--------	--------	------------
pH (units)	6.1	7.6	7.2	7.2	7.2	---------	4.5-9.0	4.5-9.0	5.0-9.0
Temperature (Deg C)	8.5	7.0	8.5	7.0	7.0	---------	(c)	(c)	(c)
Sodium-adsorption ratio	.4	24	1.6	7.1	10	---------	8-18	8-18	------------
Aluminum - Al, dissolved (μg/l)	20	10	0	10	190	5,000	5,000	20,000	------------
Arsenic - As, dissolved (μg/l)	1	6	4	0	4	200	100	2,000	100
total (μg/l)	5	35	18	2	27				
Beryllium - Be, dissolved (μg/l)	< 10	< 10	< 10	< 10	< 10	(c)	100	500	------------
total (μg/l)	< 10	< 10	< 10	10	< 10				
Boron - B, dissolved (μg/l)	490	70	110	90	70	5,000	750	2,000	(g)
Cadmium - Cd, dissolved (μg/l)	0	< 1	1	< 1	1	50	10	50	10
total (μg/l)	10	10	20	20	20				
Chromium - Cr, dissolved (μg/l)	0	10	< 10	10	< 10	1,000	100	1,000	50
total (μg/l)	20	150	50	70	70				
Copper - Cu, dissolved (μg/l)	5	8	4	0	4	500	200	5,000	100
total (μg/l)	70	160	130	60	200				
Lead - Pb, dissolved (μg/l)	5	5	5	4	4	100	5,000	10,000	50
total (μg/l)	300	700	600	400	200				
Lithium - Li, total (μg/l)	700	50	110	40	50	---------	2,500	2,500	------------
Manganese - Mn, dissolved (μg/l)	1,900	30	120	450	30	(c)	200	10,000	50
total (μg/l)	2,000	450	530	880	330				
Mercury - Hg, dissolved (μg/l)	0.0	0.0	.3	0.0	2.1	10	--------	--------	2
total (μg/l)	0.0	0.0	1.5	0.0	1.2				
Molybdenum - Mb, total (μg/l)	3	15	0	3	0	(c)	10	50	------------
Nickel - Ni, dissolved (μg/l)	10	1	3	1	3	---------	200	2,000	------------
total (μg/l)	< 50	100	50	50	50				
Selenium - Se, total (μg/l)	0	0	1	0	5	50	20	20	10
Vanadium - V, total (μg/l)	(h)	(h)	(h)	(h)	(h)	100	100	1,000	------------
Zinc - Zn, dissolved (μg/l)	400	100	800	470	200	25,000	2,000	10,000	500

a/ See text for explanation of well-numbering system.
b/ (EPA, 1973, p. 48-104, 304-345).
c/ EPA concluded no recommended limit necessary.
d/ Dependent on annual average of maximum daily air temperature over at least a 5-year period.
At the Rawlins FAA station, the annual average of maximum daily air temperature is 53.2°F for the period 1968-73.
e/ No recommended limit for NO_2 and NO_3 as total N; recommended maximum for nitrite is 1 mg/l.
f/ Recommended guidelines are dependent on many factors (EPA, 1973, p. 335).
g/ More information required.
h/ Deleted, unable to determine due to interference.

In one or more samples, the concentrations of iron, sulfate, nitrate, ammonia, cadmium, chromium, copper, lead, manganese, mercury, and zinc all exceed the recommended standards for these constituents in drinking water. The concentrations of total lead in all samples exceed the recommended standard for lead in livestock supply water. The concentrations in one or more of the samples of total and dissolved iron, total cadmium, total chromium, total and dissolved manganese, and molybdenum and the sodium-adsorption ratio in one sample, exceed the standards for water used for continuous irrigation. The concentrations of total iron in three samples and the sodium-adsorption ratio of one sample exceed the standards for water use for up to 20 years of irrigation on neutral to alkaline, fine textured soils.

From these results, it can be assumed that the chemical quality of this water makes it of questionable value for irrigation. Moreover, this water, if put into Seminoe Reservoir or even pumped into an infiltration pond could have detrimental effects.

Effects of mining on area hydrology

Potential effects on surface and subsurface water supplies

Surface water

Water supply of the streams in the area is meager, as was explained earlier. Even so, the mining operations will have little effect on the area runoff. Precipitation will be intercepted by the mine pits; however, this water must be removed for operation of the mine. High sediment concentrations may occur from runoff of reclaimed areas until a vegetative cover has been established.

Subsurface water

When mining extends into the water-saturated coal beds, the coal company will have to pump water from the mine. This will produce a gradient in the potentiometric surfaces toward the mine. There are no major supply wells in the area that will be affected and the local springs flow seasonally and are relatively unimportant in their contribution to the reservoir. Recharge to the aquifers will be affected by their removal during mining and by disturbance of drainage patterns. When runoff that normally would recharge the aquifer flows into the mine, it will be pumped out and possibly be removed from the area by surface drainage and will not recharge the aquifer. A depression, formed if the volume of the mined coal greatly exceeds the volume of the overburden, would act as a collection point for surface water. If the depression extends below the water table, ground water would flow into it and be removed from the area by evaporation or surface drainage. If the depression

is above the water table, it could act as a collection point of precipitation and surface runoff that could infiltrate and recharge subsurface supply.

Seminoe Reservoir may be directly affected by mine dewatering. Water from the mine may go directly into the reservoir, increasing supply. The connection between Seminoe Reservoir and underlying aquifers is unknown, particularly the effects of faulting. Mine dewatering may increase flow from the reservoir to the subsurface, decreasing surface supply, if no water is returned to the reservoir.

An aquifer test in the area where mining will occur will help estimate the effect of mine dewatering; its radius of influence and the discharge necessary to dewater to a certain depth. Long-term records of water levels in the area are necessary to evaluate the relationship between Seminoe Reservoir and the aquifers. Information on current dewatering activities at the Medicine Bow Number 1 Mine, south of the study area, could be used for predicting conditions in the study area.

Drainage and pollution hazards that could occur if mining occurs

Surface water

Any hazards due to dewatering activities would be functions of the discharge volume and the volume and the quality of discharges from other mines and developments in the drainage basin. The discharge of one mine may not appreciably effect the water quality of the surface waters, but in conjunction with other discharges in the same drainage would be detrimental. If dewatering of the mine pit is necessary, the pumped water should not be discharged into stream channels.

Artificial increase of flow in ephemeral channels can cause accelerated erosion. Even a small discharge of less than several cubic feet per second would wet the streambed, making it more susceptible to erosion when a flood occurred. A discharge of over several cubic feet per second, such as could occur from the combined dewatering activities of several mines, would have potential of causing accelerated erosion of stream channels. Flows of over several cubic feet per second would have sufficient velocity, depending on local conditions, to pick up and transport material from the sandy streambeds. A discharge of over several cubic feet per second, depending on local conditions, would have potential of causing accelerated erosion of the stream channel.

Subsurface water

If ground water from a mine in the study area enters the surface drainage, it could have a detrimental effect downstream. This effect may be the result of the accumulated additions of water from this and other developments in the same drainage. The study area is adjacent to Seminoe Reservoir and is in the Platte drainage. The effect of the quality of the discharged water, particularly the concentrations of some ions mentioned before, on the reservoir and other downstream conditions should be considered in mine plans. Wyoming law requires a permit for any discharge.

If the water from the mine is diverted to infiltration ponds, the concentration of some elements could increase because of evaporation, possibly to toxic levels.

It is unknown how water flowing through refill material is affected. Leaching of some elements from this refill could degrade ground-water quality. This possibility should be investigated further by installing observation wells in refill material.

Water quality, with respect to the dewatering of any mine in saturated coal beds, should be monitored closely for how it may affect downstream conditions, livestock in the area, and the revegetation of the area.

LEGAL REQUIREMENTS ON MINELAND RECLAMATION

Federal

Legislation now pending before the Congress. We expect the strip-mining bill to become law before the Final Report is prepared in June 1975.

State of Wyoming

Prior to 1969, Wyoming had no laws requiring mine spoils to be reclaimed. In 1969, the Open Cut Land Reclamation Act became law. It applied to the surface mining of all mineral resources in Wyoming, including those on Federal land, excepting Indian land. This Act required for reclamation:

- surety bonding equal to reclamation costs;
- minimum guidelines for grading;
- reseeding required whenever "practicable";
- an annual report of reclamation (including a map); and
- liberal timing requirements for reclamation - these were left to the State Land Commissioner's discretion.

Under the Open Cut Land Reclamation Act, the coal companies reported they had reclaimed nearly one-half the surface acreage affected between 1969 through 1971. About 29 percent of the total surface acreage disturbed by surface coal mining prior to 1971 is considered by the state to have been reclaimed under the minimal standards of the 1969 Act. The 1969 Act did not require reclamation of land disturbed prior to its enactment.

In 1973, a new law was passed, entitled the Wyoming Environmental Quality Act of 1973. It is designed to regulate land development and control the pollution of air, water, and land within the state.

The 1973 Act pertains to all types of underground mining as well as surface mining. Some of the important features with regard to reclamation are:

1. It repeals the 1969 Act.

2. It establishes a nine-man board to administer the Act in place of the Land Commissioner. This board is appointed by the Governor.

3. It requires issuance of an operator's license and mining permits and sets provisions for denial of permits.

4. It requires advertisement of mining permit applications, and provides for filing objections to the application and public hearings.

5. It requires land disturbed by mining to be returned to a use of equal or greater value than its prior use.

6. It requires a mining plan showing the nature and extent of the mineral resources, the land to be mined, and a description of mining operations with a time schedule.

7. It requires a reclamation plan prior to issuance of a mining permit. This plan must include:

   a. Cost estimates for reclamation.
   b. Maps showing extent of reclamation, which must be periodically updated.
   c. Methods of regrading and recontouring the affected land.
   d. Methods of stockpiling, preserving, and returning the topsoil.
   e. Methods and plants used for revegetation.

8. It requires the prevention of water pollution from mine spoils.

9. It sets time limits on reclamation and can raise the surety bonding requirements.

10. It requires the consent of the surface owner (if different from the mineral owner) to both the mining and reclamation plans.

Local

To the best of our knowledge, no local strip mining laws have been enacted or are now being enforced.

ALTERNATIVE METHODS OF RECLAMATION

Objectives of reclamation

The land which overlies the coal seams of the Hanna Basin is rangeland in the truest sense of the word. It has, in the past, been considered to be of low economic value, and is used as range for domestic livestock and wildlife. In order to strip mine the coal resource it is necessary to remove the topsoil and overburden materials and replace it in such a manner that the affected areas can attain equal or greater productivity than existed prior to mining. This of course, is the main objective and challenge of reclamation of future strip mined sites in the basin.

To return these lands to a desirable form and use, it is necessary to know a great deal about where, why, how, and when, of the surface lands and accompanying resources. These questions should not only be applied to the area proposed for strip mining, but also the surrounding areas which will undoubtedly be affected by the mining operation. For example, it is necessary to know what these lands are like prior to mining with regard to their soil, vegetation, water, and animal resources. The preceding information provided in this report fulfills this need.

Reclamation of mine spoils must also recognize that the basic ecology ofthe area is drastically changed from its original state prior to mining. Mine spoils are, in reality, new and unique ecosystems in regard to their attributes and ecological processes, and must be thoroughly understood and evaluated before recommendations are made for the reclamation of the mined land. An area that has been disturbed by surface mining seldom reaches the same ecological equilibrium that existed prior to the disturbance. This is especially true when major alterations of soil, topography, and living organisms are made during the disturbance such as are presently being made in the removal of coal in the Hanna Basin. Strip mining, is a drastic environmental change. Successful reclamation can be accomplished only when thorough analysis planning is done prior to the actual mining. Reclamation objectives being considered in this study include evaluation of the overburden material and how it must be shaped and treated in order to support desirable plant life, prevent soil erosion both by wind and water, prevent water pollution (either ground or surface waters) and maintain or enhance the aesthetic values. These objectives can be accomplished through careful planning and management, including

monitoring of mining techniques, reshaping the spoils, use of methods or structures to control erosion, careful prevention of damage to hydrologic systems, selection planting, and adapted species of grasses and shrubs and management of the lands after revegetation has been accomplished.

Management objectives, or general physical qualities, that are covered in this report and which should be considered for incorporation in future leases and reclamation plans for the Hanna Basin are as follows:

1. Provisions for removal, stockpiling and replacement of soil and overburden materials during strip mining operations. This will lead to creation of a surficial soil condition capable of supporting a density and type of plant life equal to that which the site originally supported and that of surrounding undisturbed lands.

2. Recommendations which will result in creation of final topography which will blend with the form of the adjoining undisturbed landscape.

3. Designs which will create a positive surface drainage pattern with no dead-flat areas to promote ponding or steep areas which will result in gullying.

4. Provision for establishment of full ground cover planting for erosion control and soil stabilization as soon as surface soil conditions allow.

5. Provision for management and use of lands after rehabilitation is started and for a reasonable period after new vegetative plantings have been made and have become established.

Evaluation of site soils and overburden material as plant growth media

Soils

The naturally occurring soil profiles within the study area generally show few major problems relative to the potential suitability as a plant growth medium. Two mapping units, No. 8001 and 8020, however, have characteristics which render them less than desirable as a source of surface backfill material.

Mapping unit No. 8001, classified as a Ustic Torriorthid, is generally satisfactory from a chemical standpoint, for use as a plant growth medium. Soil textures within this unit, however, are generally too fine textured to be ideally suited for surface backfill. These clays would not be sufficiently permeable nor friable

to obtain good seed germination or plant growth, nor would an adequate level of organic matter or available nitrogen be easily achieved on a long-term basis. These mapping units show good depth, however, and their use (particularly as mixtures with lighter textured material) might be advisable should a shortage of more suitable materials occur.

Mapping unit No. 8020, classified as a Boralic Natragid, exhibits chemical properties which would be adverse to seed germination and plant growth. Relatively high levels of exchangeable sodium, coupled with somewhat high levels of soluble salts, are indicators of a less than ideal condition for use of these soils as a backfill material.

With the exceptions discussed above, most of the developed soils within the site will provide suitable plant growth material if placed upon the surface of the reformed mine strip. Mapping unit No. 8040 (Borollic Camborthid) is a suitable plant growth material source, but has a high gravel and cobble content, and should probably be mixed with finer textured material to avoid low water holding capacity difficulties.

Mapping unit No. 8050 (rough, broken land) represents a land type rather than a developed soil profile. Since it is comprised of rock outcrops, eroded areas and very shallow lithosols, it does not represent a suitable source of backfill material for use as a plant growth medium.

Soil profile depths within the study site are generally somewhat shallow, and it is doubtful that the developed soils of the area would provide a sufficient quantity of material to act as an adequate topsoil when placed over the reformed and shaped spoil piles. For this reason, it is necessary to consider the physical and chemical properties of the overburden materials underlying the developed soils, since it is relatively certain that the more suitable of these will have to be utilized as plant growth media during reclamation operations.

Overburden materials

Overburden materials within the study site vary widely in both chemical and physical properties and, consequently, in suitability for use as plant growth media. Of particular interest are those materials which are unsuitable by reason of adverse chemical properties and/or trace element toxicity.

As can be seen from the tabulation of laboratory test results, shown previously in table 18, the following overburden layers have

deficiencies which render them unsuitable, or at least doubtful, from a chemical standpoint, for use as plant growth media.

Deep Hole No.	Depth in Feet	Deficiency
D-9001	1.5-3.4	pH 1:5-5.9, $pHCaCl_2$-4.1
	3.4-7.7	$ECx10^3$ (sat. ext.)-8.03
	9.8-15.0	pH 1:5-5.6, $pHCaCl_2$-4.6
	15.0-21.5	pH 1:5-4.4, $pHCaCl_2$-4.0
	21.5-24.7	pH 1:5-4.6, $pHCaCl_2$-4.2
	24.7-29.0	pH 1:5-6.0, $pHCaCl_2$-5.4
	29.0-35.0	pH 1:5-6.0, $pHCaCl_2$-5.5
	112.4-126.4	Coal

The depths from 0-1.5 feet (developed soil), 7.7-9.8 feet, 41.0-112.4 feet and 132.0-201.8 feet appear to consist of materials which would be chemically suitable for use as plant growth media.

Deep Hole No.	Depth in Feet	Deficiency
D-9002	5.9-30.4	Acid pH, high $ECx10^3$
	61.7-69.3	Acid pH
	69.3-75.5	Coal
	104.7-200.8	High pH (SAR values high)

The depth of 1.4-5.9 feet, 30.4-43.9 feet and 75.5-89.1 feet appear to be of doubtful suitability, or at least of less desirability than the layers at depths of 0-1.4 feet (surface soil), 43.9-61.7 feet and 89.1-104.7 feet.

Deep Hole No.	Depth in Feet	Deficiency
D-9003	1.3-4.6	High $ECx10^3$, pH 8.5 (SAR values high)
	4.6-62.6	High $ECx10^3$ (Some low H_2O holding capacities)
	72.4-88.9	Low H_2O holding capacity
	98.2-102.6	Low H_2O holding capacity

The depths of 0-1.3 feet (developed soil), 62.6-72.4 feet, 88.9-98.2 feet and 102.6-150.4 feet appear to be suitable for use as surface backfill material.

Deep Hole No.	Depth in Feet	Deficiency
D-9004	2.0-10.0	$ECx10^3$ (high salts)
	42.0-48.9	Coal
	48.9-58.5	High salts
	58.5-114.1	High SAR values -Low holding capacity
	114.1-172.8	Low H_2O holding capacity
	172.8-201.4	High SAR values

The layers of from 0-2.0 feet (surface soil) and 10.0-42.0 feet appear to be sources of suitable surface backfill for plant growth.

Deep Hole No.	Depth in Feet	Deficiency
D-9005	0-1.1	High salts - Low SAR
	1.1-9.0	High salts - Low SAR
	9.0-35.0	Low pH 1:5-5.3
	49.7-58.2	Low Perm - high SAR values
	58.2-196.5	High pH (high SAR values)

The depths of 0-1.1 feet (surface soil), 1.1-9.0 feet and 35.0-49.7 feet are marginal, and could possibly be satisfactory plant growth media, with this exception, this entire hole is unsuitable.

Deep Hole No.	Depth in Feet	Deficiency
D-9006	6.6-44.4	Acid pH
	44.4-46.6	Coal
	46.6-53.5	Low Perm - high SAR value
	58.3-100.0	High Na (high SAR values)

The layer from 0-2.5 feet (surface soil) appears to contain suitable material. From 2.5-6.6 feet was not sampled, but appears to have marginal suitability.

Deep Hole No.	Depth in Feet	Deficiency
D-9007	5.8-16.6	Low H_2O holding capacity
	16.6-24.5	Low $pHCaCl_2$-5.0
	24.5-35.5	Coal and shale
	35.5-55.1	Low cation exchange
	56.3-65.0	Low H_2O holding & cation exchange capacities
	82.5-93.5	Coal
	93.5-106.3	Low H_2O holding & cation exchange capacities

The layer from 2.7-5.8 feet was not tested but would likely be of marginal suitability. The 35.5-55.1 foot layer has a somewhat low cation exchange capacity value, and the 56.3-65.0 foot and the 93.5-106.3 foot layers have low water holding potentials. The layers from 0-2.7 feet and 66.8-82.5 feet are considered suitable.

Deep Hole No.	Depth in Feet	Deficiency
D-9008	21.4-32.7	High salts
	32.7-33.5	Coal
	33.5-52.9	High salts, low pH
	52.9-76.5	Low cation exchange capacities
	76.5-82.7	Coal
	89.1-103.2	Low cation exchange capacities
	104.6-111.5	Coal
	111.5-166.8	High SAR values
	166.8-203.5	Low cation exchange capacities

The depths of 0-21.4 feet, and 82.7-89.1 feet appear to offer a source of suitable plant growth material.

There are many varied geologic dips and strikes, as well as some faults, in the study area. Because of this situation a cross-section map showing selected overburden materials between drill holes would be very difficult. To project this suitability with confidence, the drill holes would have to be located about 1900 feet apart (assuming a 6° dip minimum which is about the least dip angle in the area). This number of detailed drill holes would be time consuming and expensive. However, saturation drilling, as was mentioned in the geology portion of this report, could be used to correlate these beds with a reasonable amount of accuracy.

A comparison of the suitabilities just discussed, along with the various rock types encountered in the overburden material, has been outlined earlier in this report in the geologic log presentation.

Physical characteristics which may limit the practical use of overburden materials (outside of those already covered in the tests for permeability and water holding capacity) include hardness of the rock, resistance to weathering, coloration (dark materials may cause problems due to energy generation and high temperatures), etc. At the present stage of the testing program, it is not apparent that any significant physical problems of this type are present. The addition of a topsoil layer over these materials should render them relatively suitable in practice.

Evaluation of water supply for reclamation purposes

Because of the low natural moisture regime in the Hanna site, there is the possibility that the revegetated areas in the study site will require a supplemental water supply during the early stages of revegetation. As previously summarized, the site hydrology indicates that the subsurface water would be inadequate in supply and quality for irrigating revegetated areas. However, adjacent to the site is Seminoe Reservoir which is one of a network of reservoirs, on

the North Platte River, in the North Platte Projects area. Possibly, a source of water could be obtained from this reservoir on a short-term contract basis. The water would be suitable as a supplemental source as shown in the following summation taken from the Water Resources Data for Wyoming Water Quality Records - 1973.

North Platte River Above Seminoe Reservoir
(14 miles upstream from high-water line)
October 1972 to September 1973

	Total Dissolved Solids	SAR	Specific Conductance
Low	141 ppm	0.5	225 ec x 10^6
High	410 ppm	1.3	633 ec x 10^6
Mean	298 ppm	0.9	470 ec x 10^6

Medicine Bow River Above Seminoe Reservoir
(9.0 miles upstream from high-water line)
October 1972 to September 1973

	Total Dissolved Solids	SAR	Specific Conductance
Low	371 ppm	0.9	560 ec x 10^6
High	935 ppm	2.2	1,300 ec x 10^6
Mean	691 ppm	1.5	990 ec x 10^6

Data from previous years also indicate the quality to be suitable for supplemental irrigation.

Measures required to prevent adverse effects on surface and ground waters of area

If dewatering of the mines is necessary, the pumped water should not be released to stream channels. The water should be released to a reservoir, constructed especially for this purpose. A permit will be required for any discharge.

Reclaimed land should be contoured so that resulting stream channels will have slopes equal to or less than those encountered before mining. Contour furrowing should be done to temporarily minimize runoff until a grass cover has established. Where possible, small settling ponds should be constructed to capture sediment-laden runoff from disturbed areas.

Proposed surface material as planting media

Source of material

Sources of plant growing material are discussed in some detail under "Potential Plant Growing Material" and "Evaluation of Site Soils and Overburden Material as Plant Growth Media." This section outlines the suitability of both surface soils and overburden materials specifically found on the study site for use as plant growth media.

It should be pointed out that existing surface soils, wherever suitable, should be stockpiled and utilized as top priority plant growth material. It is generally felt that this material is basically more inherently suitable for revegetation work due to its higher organic matter content, better physical condition, and ease of physical handling as well as the fact that there are relatively large numbers of native seeds present which will aid in vegetation establishment.

Suitable overburden materials outlined in "Evaluation of Overburden Material as Plant Growing Material" are anticipated to be used as surface material for plant growth media, since it is quite clear that there will not be a sufficient quantity of suitable topsoils to use as the total plant growth medium. The acquisition and stockpiling of these suitable overburden materials should be relatively easy and economical in the course of the mining operation, since total overburden removal is part of the continuing mining procedures.

Suitability as a growing medium

Here again, as outlined above, a rather complete discussion of this subject is contained in "Potential Plant Growing Material" and "Evaluation of Site Soils and Overburden Material as Plant Growth Media." Very little can be added with the exception of some remarks on special considerations required for successful revegetation procedures. In this connection it should be noted that where highly pulverized overburden materials are to be used at the surface, it will be necessary that caution be exercised to maintain proper physical conditions for plant growth. Avoidance of undue compaction caused by machinery operation will probably be important, particularly when the materials are damp. It may also be necessary to rip or chisel compacted materials where finer textured overburden materials are used as a plant growth medium.

The following discussion, tables and maps pertain to the surface soils of the study site only, and do not address the subject of suitability of overburden materials as a source of plant growth material.

In the Hanna Basin site a rating was made to determine the suitability of surface soils as a source of growing medium. The growing medium, in this case, is defined as that soil material to be used as a base for revegetation purposes.

Limitations and ratings were derived from parameters established in table 28, which is modified from a Bureau of Land Management technical release (Rel. 7-55). Rock outcrops and degree of outcrops were also considered and field judgements were used with these parameters.

Table 28 - Suitability Ratings of Soils as Sources of Topsoil

Item affecting use	Degree of soil suitability: Good	Fair	Poor
Moist consistence	Very friable, friable	Loose, firm	Very firm, extremely firm
Permeability	0.80-2.50 in/hr	0.20-0.80 in/hr	Less than 0.20 in/hr
Texture	fsl, vfsl, l, sil; sl; sc if 1:1 clay is dominant	cl, scl; sicl; sc if 2:1 clay is dominant; c and sic if 1:1 clay is dominant	s, ls; c and sic if 2:1 clay is dominant
Available water holding capacity	Greater than 6 in.	3-6 inches	Less than 3 in.
Depth Inches	More than 16 in.	8-16 in.	Less than 8 in.
Coarse fragments; percent, by volume	Less than 3 pct	3-15 pct	More than 15 pct
$ECx10^3$ @25°C	Less than 4 mmhos/cm	4-8 mmhos/cm	More than 8 mmhos/cm
Sodicity	Less than 8% exchange sodium	8-15% exchangeable sodium	More than 15% exchangeable sodium
Stoniness class 1/	0	1	2, 3, 4, and 5
Soil drainage class 2/	Drainage class not determining if better than poorly drained		Poorly drained, very poorly drained

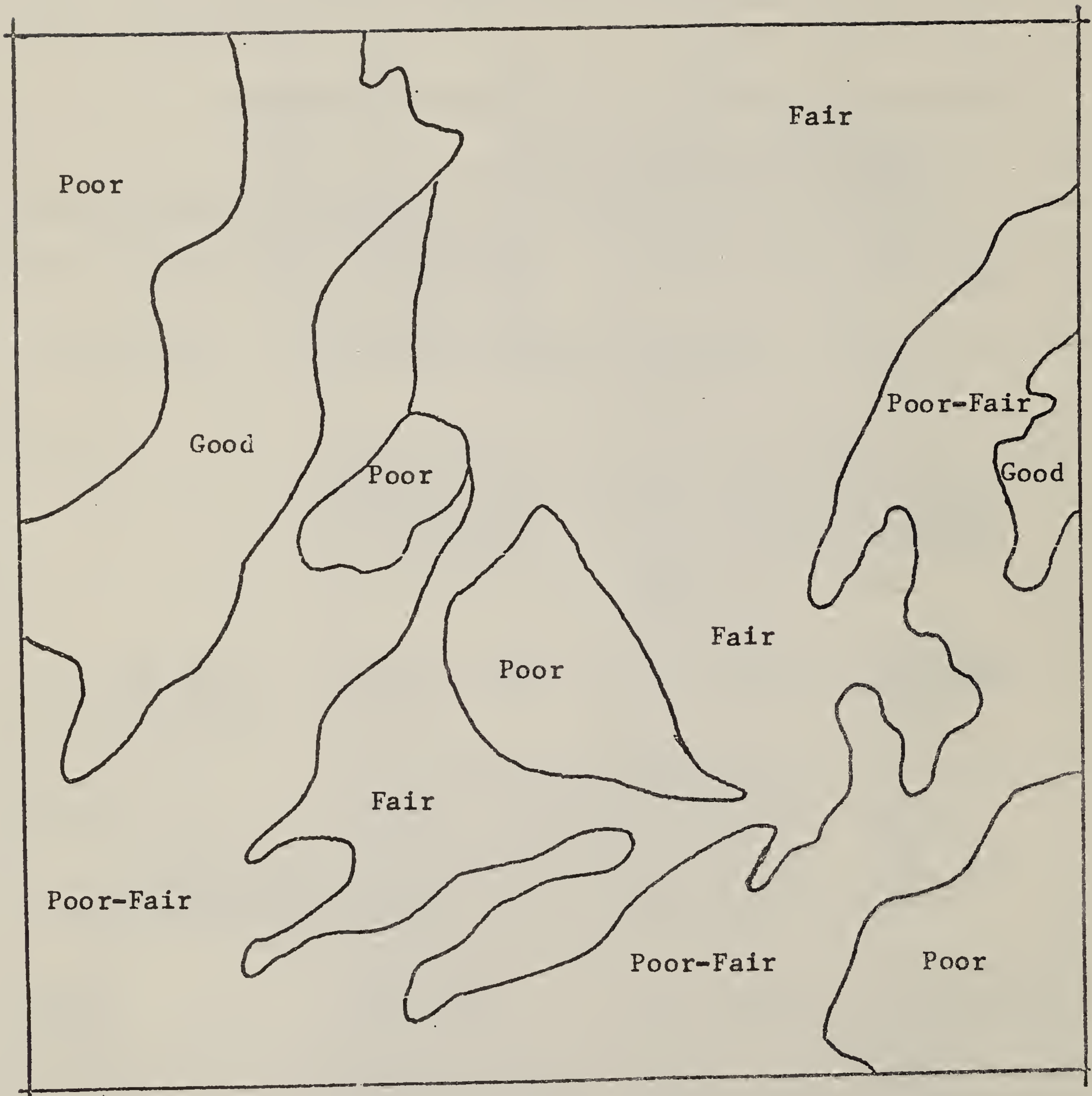
1/ For class definitions see Soil Survey Manual, pp. 216-223
2/ For class definitions see Soil Survey Manual, pp. 169-172

The suitability ratings along with several of the parameters used for the five soil series and one Rock land type are as follows:

Soil Series	Slope	Depth Inches	Texture	Est. Coarse Frag.	Est. Soluble Salts	Limitations	Rating
8001	0-3A	32/60	c	0	4	Cons, tex, permeability	Poor
8010	3-7B	36	sl/scl/sl	0	4	-	Good
8010	7-12C	36	sl/scl/sl	0	4	Water holding capacity	Fair-Good
8020	0-3A	20	sl/scl/sl	0	4-8	Salts, sodicity	Fair
8020	3-7B	20	sl/scl/sl	0	4-8	Salts, sodicity	Fair
8020	7-12C	20	sl/scl/sl	0	4-8	Salts, water holding capacity	Poor-Fair
8030	3-7B	10	sl/l	0	4	Thin layer	Fair
8030	7-12C	10	sl/l	0	4	Water holding capacity	Poor-Fair
8030	12-20D	10	sl/l	0	4	Thin layer slope, water holding capacity	Poor
8040	0-3	40	gl/cobl/gl	15+%	4	Coarse frag.	Poor
8040	7-12	40	gl/cobl/gl	15+%	4	Coarse frag.	Poor
8050	ROCK LAND (MLT)		-	-	-	No Soil	Poor

Suitability maps, showing the delineations and ratings, are given in exhibits 6 through 10. These exhibits can be correlated with the soil survey maps, exhibits 1 through 5 which indicate the soils in more detail.

Exhibit 6

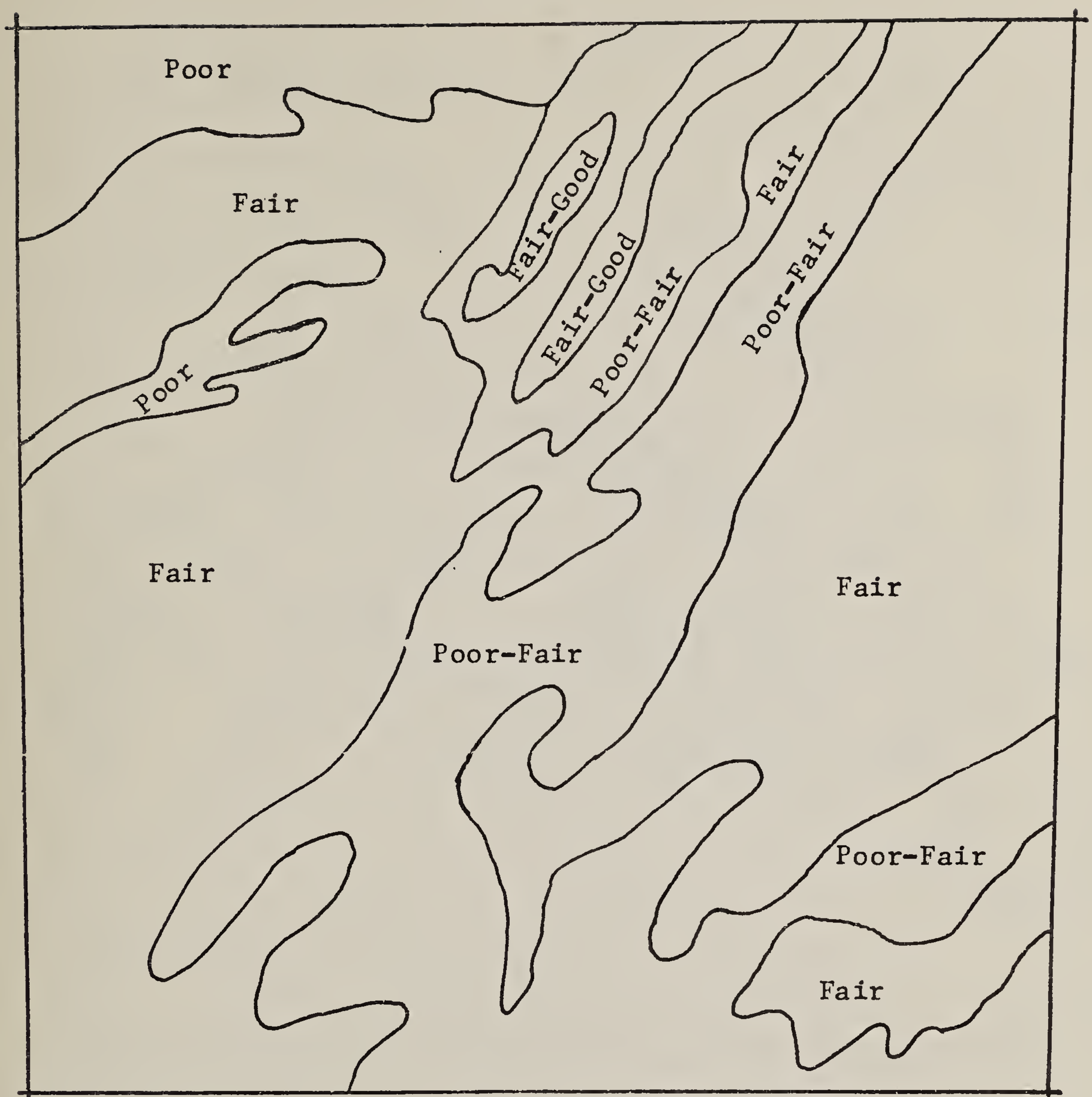


Section 12

Scale 1 : 12,000

1000 0 1000 FT.

Exhibit 7



Section 6

Scale 1:12,000

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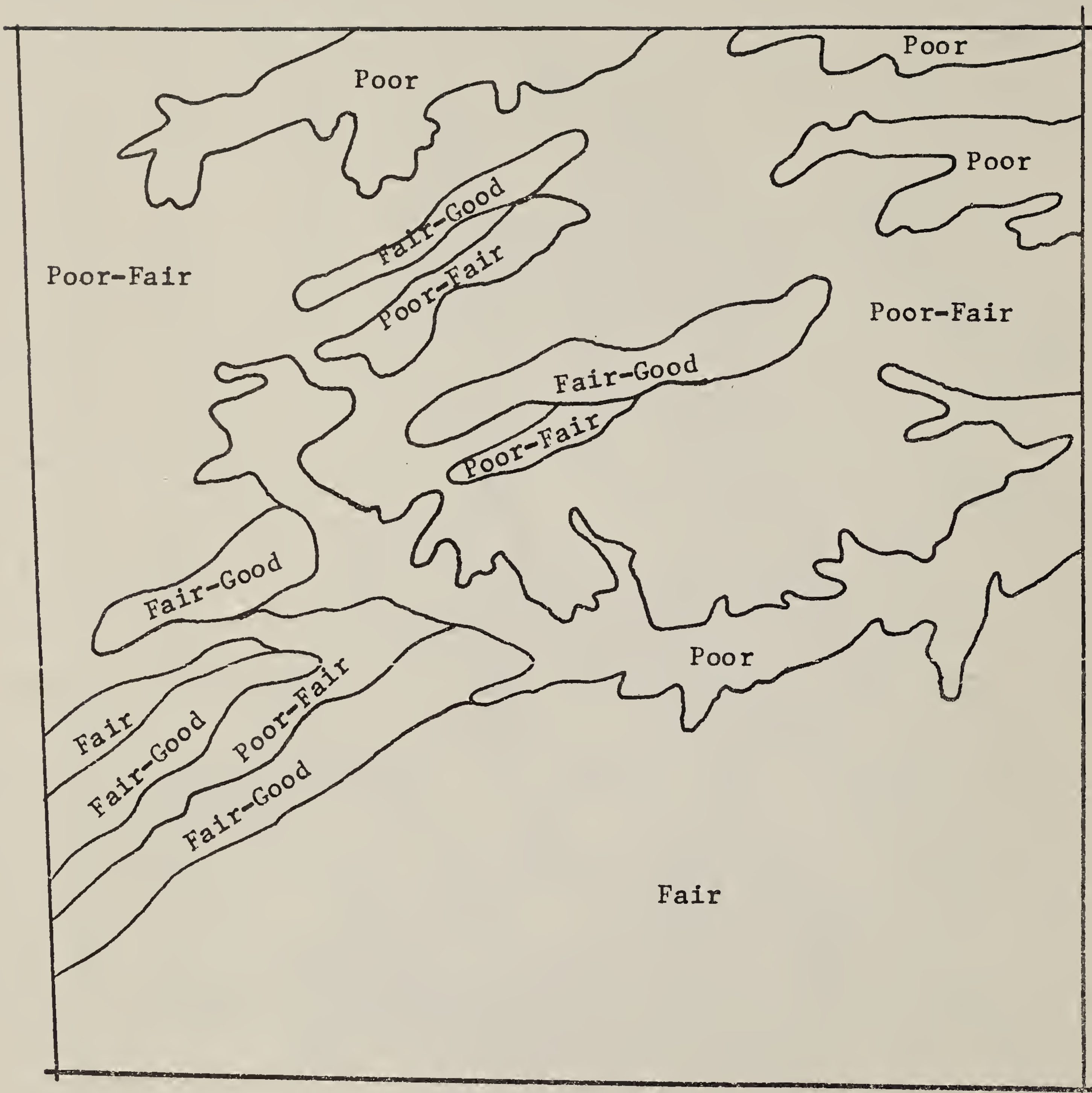
Exhibit 8



Section 32

Scale 1:12,000

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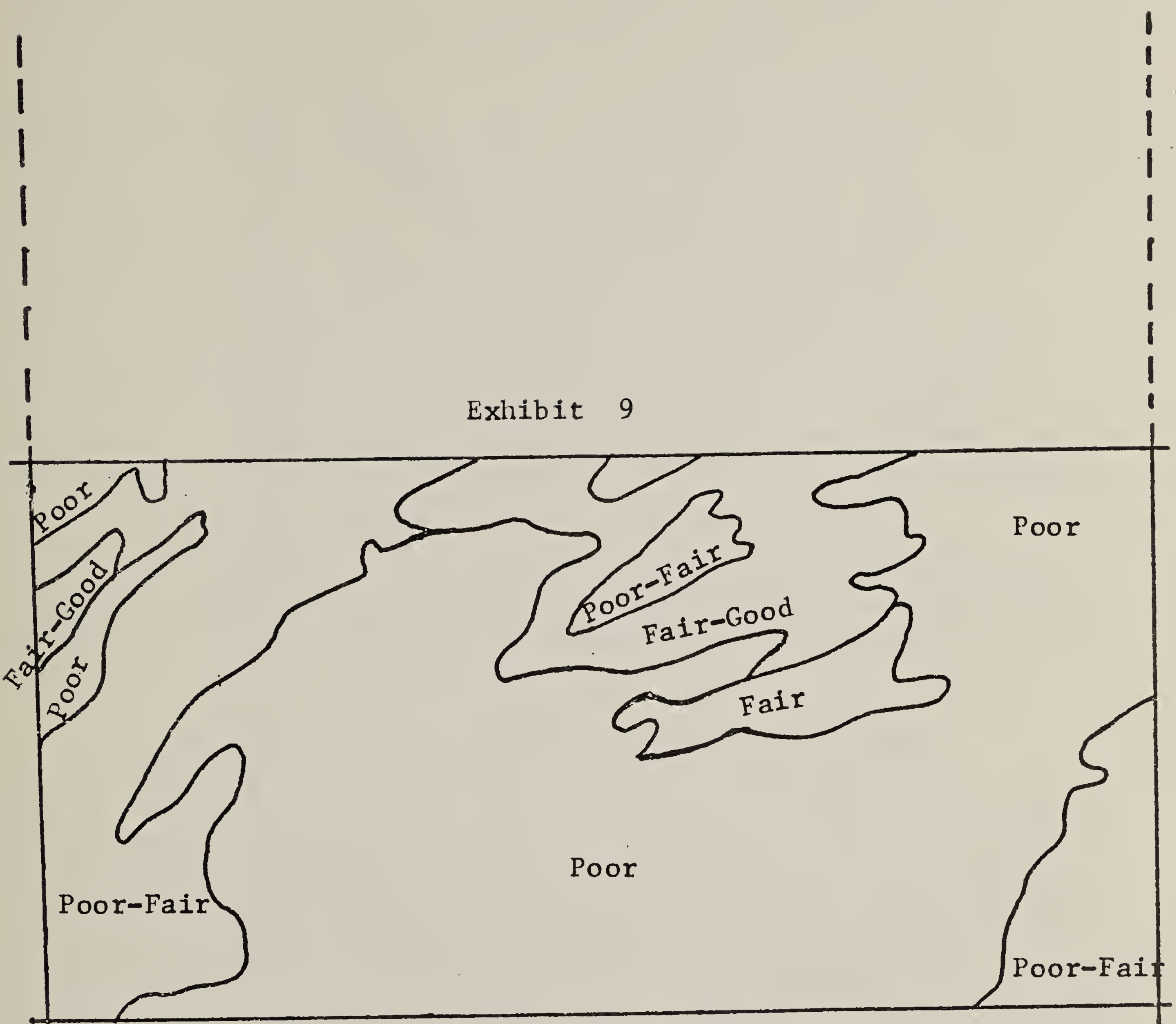
Exhibit 9



Section 30

Scale 1:12,000

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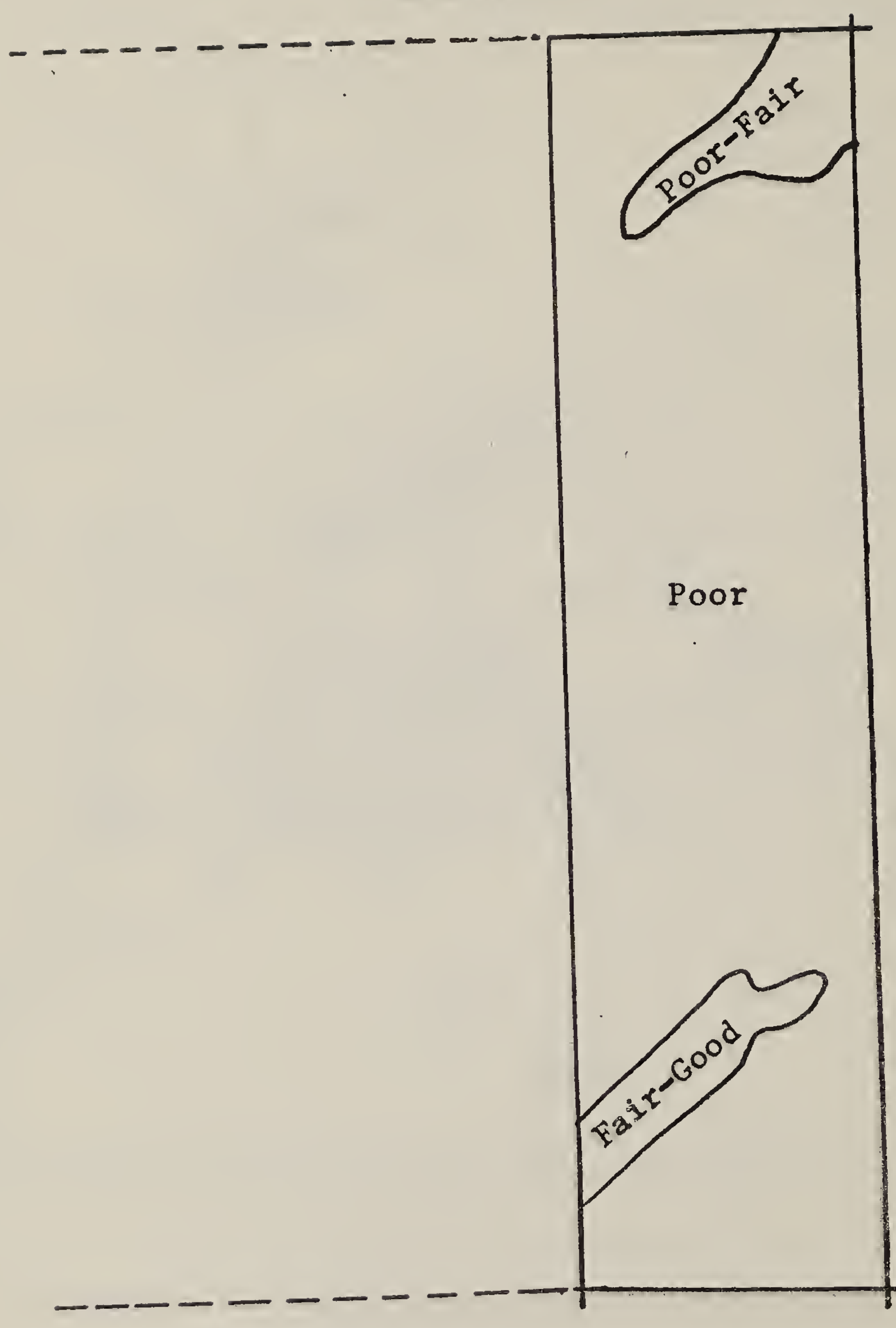
Exhibit 10



Section 36

Scale 1:12,000

1000 0 1000 FT.

Handling and placement of overburden and plant growth media and disposition of toxic materials

The primary factor to be considered in the physical manipulation of the materials disturbed in the actual mining operation will, in all probability, be the proper disposition of any toxic materials encountered. Those materials which are unsuitable for plant growth as outlined in "Evaluation of site soils and overburden material as plant growth media," particularly those having acid pH values, should be placed in such a way, and at such a depth, that they will not come in contact with the root zone of the re-established vegetation. This will require that these materials be separated and identifiable during the mining operation for later disposal at depth. It would seem advisable that acid materials not be placed closer than 15 feet of the reformed surface. The plant growth media selected will likely be a combination of suitable surface soils and pulverized overburden materials. The suitability of these materials is discussed in "Potential plant growing material" and "Evaluation of site soil and overburden material as plant growing media." It will be necessary that the suitable plant growing materials be stockpiled in a readily identifiable way during the mining operation so that they can be placed upon the surface during final forming of a reconstructed landform. Care will need to be exercised during handling of these materials to avoid undue compaction of the plant growing material.

Requirements for special treatments or practices

Some of the important special treatments or practices that should be considered in the reclamation of strip mined sites in the Hanna Basin include the possibility and practicability of supplemental irrigation to establish ground cover and desirable native grasses and shrubs; surface grading to obtain desirable topography from the erosion control and esthetic viewpoints; manipulation of the graded surface (such as ripping or chiseling, contour furrowing, pitting, and floodwater spreaders) to trap scant moisture and concentrate it as a soil moisture reserve and to prevent surface erosion; and surface soil protection from wind and water erosion, such as installation of wind barrier snow fences and surface mulches.

Supplemental irrigations

Supplemental irrigation to establish new seedlings in this area is a possibility; however, its practicability can be questioned. It was pointed out earlier in the report that the groundwater in the study area was of questionable quality and should not be used for irrigation purposes in the reclamation of mined areas. Therefore, the only source of water which could be used to irrigate new seedings in the reclamation program is a Bureau of Reclamation facility, Seminoe Reservoir. Because of the difference in elevation

between the reservoir water surface and lands to be reclaimed, it would be necessary to pump water through pipelines for fairly large distances, both horizontally and vertically. In order to adequately germinate and establish desirable plants on the denuded areas, it is estimated that a minimum of 3 years irrigation during the growing season would be required. After the 3-year period of intensive irrigation and fertilization was completed, it would then be necessary to "wean off" the irrigated seedings so that they could be sustained under existing rainfall and climatic conditions. Experience indicates that the shock of removing supplemental irrigation and regular fertilization can become so damaging that many so-called "established stands" of native grasses and forbes have succumbed to the rigors of nature, thus leaving an area open for erosion and further degradation. After thoroughly studying all growing factors and the climate of the Hanna Basin, it was the consensus of federal agencies preparing this report that supplemental irrigation should not be used in the revegetation plan unless all of the other tested and proven dryland methods for establishing native vegetation, common and adapted to this area, fails.

Surface grading

Effective shaping of spoils to a preconceived design is essential to these lands so that they blend in with the adjacent topography of undisturbed lands and to minimize drainage problems. In the study area, it is recommended that the spoil piles be placed back in the pit and graded to a rolling type topography with slopes not steeper than 3:1, or wherever possible, they should preferably be graded to a 4:1 or 5:1 slope. To further aid in the re-establishment of vegetation in the area, topographic plans for the finished area should maximize north and east facing slopes. South and west facing slopes are traditionally drouthier and hotter slopes, thus making them much more difficult to revegetate. Drainageways should be provided in the topographic design of the areas and grades should be flat enough to prevent gullying and excessive channel erosion. Final grading should insure that no flat areas are created which will pond water unless temporary ponding is a part of the entire erosion control program for the area.

Manipulation of the graded surface

Manipulation or mechanical treatment of the surface material (plant growing media) have been used for more than 30 years to facilitate plant growth and establish new seedlings and to control damaging surface and gully erosion.

After all materials are placed back in the open pit and the fine grading and topography stabilized, it is recommended that the entire

area to be revegetated be loosened to a depth of 8 to 12 inches by ripping or deep chiseling on the contour. This operation is necessary to roughen the surface material that has become packed by equipment travel during previous operations so that the water intake is increased and surface runoff decreased and to place coarse materials or clods on the surface to prevent wind erosion during seedling establishment. It may also be desirable to use equipment which is capable of making pits in the contour furrows created in ripping or deep chiseling the surface material. The pitting further increases water intake and holds water where it falls. In areas where drainageways collect water in sufficient quantities to cause erosion, it is recommended that water spreaders be considered. Water spreaders are systems of dikes that are designed to divert floodwater from a gully onto adjacent rangeland. Because of the normal low rainfall in this area, it can be expected that water spreaders would come into play only during periods of rainstorms that are of short duration and high intensity and during periods of rapid snowmelt.

Surface soil protection

Protection of the surface soils from sustained high winds is essential during the winter months when precipitation is very erratic. This precipitation usually comes in the form of blowing snow. One economical method that has been successfully used to reduce surface erosion, trap winter snow and keep it on the site, as well as prevent injury to tender growing seedlings being established on a site, is to use wooden slat snow fencing material 5 to 6 feet in height. These fences should be installed perpendicular to the prevailing winds during the winter and spring seasons and should be located about 100 yards apart or closer if needed. The snow fence can be constructed with steel fence posts that can be driven into the soil or with wood posts that are hand set. Since heavy winds are common in the area, posts should be set not more than 10 to 15 feet apart.

Another method that has been successfully used to stabilize critical areas to enable plants to become established quickly in the surface material (plant growing media) is to mulch the surface after grass and legume seeding has been completed. Mulching nearly always shortens the time required to establish a suitable plant cover by reducing evaporation, moderating soil temperatures to promote germination and seedling growth, prevent crust, and control wind and water erosion. Any substance spread, formed or left on surface material may act as a mulch. There is an infinite variety of available mulching materials, including: straw, native hay, hay and other crop residues, sawdust, woodchips, wood fiber, bark, manure, sewage sludge, brush, jute or burlap, gravel, mulch stones, peat, paper, leaves, plastic film, and various organic and inorganic liquids.

Because of the nature of this site and availability of materials, it is recommended that the entire disturbed area be surface mulched immediately following seeding of grasses, legumes, and shrubs with either a gravel or crushed rock mulch or a native hay as straw mulch that is anchored by means of a mulch anchoring machine to keep it from being blown off of the newly seeded surfaces. The mulch anchoring operation should immediately follow the seeding operation. The native hay or straw mulch should be applied to the surface at a rate of not less than 2 tons per acre.

Gravel or crushed rock can also be selected from overburden material and used successfully as a surface mulching material. This type of mulch has advantages over most other mulches because it is permanent if the individual pieces are no smaller than 1/8 inch in diameter. If the gravel or crushed stone pieces are no smaller than this in size, the mulch cover will withstand a surface wind velocity of 85 mph. To control wind erosion the pieces must almost cover the soil surface (not less than 95%). The finer the gravel or crushed rock the less material is required to cover the ground surface.

Preparation of the seedbed, fertilization, and planting

Prior to ripping or chiseling the areas to be rehabilitated and seeded, all areas should be fertilized with phosphorus. Greenhouse studies indicate that all of the overburden samples from the Hanna Basin have a phosphorus deficiency. The triple super phosphate fertilizer should be applied at the rate of 100 to 150 pounds per acre by using the broadcast method just prior to ripping or chiseling the area. This will permit incorporation of the phosphate fertilizer into the top surface material where it will be readily available for plant growth and development. After the phosphate fertilizer has been applied and the areas to be reclaimed have been ripped, chiseled or contour furrowed, the area is then ready for seeding grasses and legumes. **Fall seeding, preferably before October 15, appears to produce best results in this area.** Also, grasses and legumes should be planted as soon as possible after final reclamation grading and ripping or chiseling in order to prevent surface erosion damage and reduce the problem of visual contrast with the surrounding landscape.

Selection of plants and suggested seeding rates

The following mixture of grasses, legumes, and shrubs are suggested for use in revegetating areas to be reclaimed and should be seeded at the rates per acre shown on the following page.

Grasses, Legumes	Seeding Rate Per Acre (pounds)
Western wheatgrass (Agropyron smithii)	5
Indian ricegrass (Oryzopsis hymenoides)	4
Thickspike wheatgrass (Agropyron dasytachyum)	4
Needle-and-thread (Stipa Comata)	3
Sand Dropseed (Sporobolus cryptandrus)	1
Yellow sweetclover (Melilotus officinalis)	2
Rye (Nurse crop) (Secale cereale)	60
Shrubs	
Four wing saltbush (Atriplex canescens)	5
Winterfat (Eurotia lanata)	6
Nuttall saltbush (Atriplex natallii)	6

Planting procedures

Planting of seed may be accomplished by drilling with either an approved disk or shoe-type grass drill, an approved hydroseeder, or by mechanical or hand broadcasting as follows:

1. Drill seeding. - Sowing the seed mixture with either an approved disc or shoe-type grass drill is acceptable. If this method is used, the drill shall be regulated to uniformly distribute the seed at the rate specified herein on the areas to be seeded. Where possible to safely operate equipment, drilling shall be done on the contour or parallel with the slopes being seeded. The drill shall be regulated so that the seed is properly placed in the soil and covered with soil to a depth not to exceed one-half inch. In the event the drill is equipped with an approved fertilizer attachment which will evenly distribute fertilizer at the recommended rate, the dry nitrogen fertilizer may be applied simultaneously with the drilling of grass seed.

2. Hydroseeding. - Seeding with an approved hydroseeder will be acceptable provided wind velocities permit uniform distribution of seed and nitrogen fertilizer slurry on the areas to be seeded. In hydroseeding operations, the mixture of seed and the fertilizer specified herein shall be properly mixed with water to form a slurry. The slurry mixture shall be prepared immediately prior to application, and shall be promptly applied on the areas to be seeded and fertilized. Slurry mixtures prepared more than 1 hour prior to application are not acceptable. The hydroseeder shall be designed so as to insure seed and fertilizer being uniformly applied at the recommended rates per acre. The hydroseeder shall be equipped with a paddle-type agitator and recirculation pump that will continually stir and mix the slurry to prevent settling of solids in corners and at the bottom of the tank and maintain a uniform mixture

of seed, fertilizer and water at all times during the entire seeding operation. Immediately after the slurry mixture is applied to the soil surface, the seed shall be properly covered with soil to a depth not to exceed one-half inch if the surface area permits.

3. Mechanical broadcasting. - A mechanical broadcaster of either the centrifugal type or pull type similar to fertilizer spreaders are acceptable. Any equipment of this type used for broadcast seeding shall be designed and regulated to insure that the proper seeding rate per acre is uniformly applied on areas to be seeded. When this method is used, seed and fertilizer may not be applied in the same mixture simultaneously; each shall be broadcast separately.

4. Hand broadcasting. - Hand broadcasting may be performed on small, inaccessible areas. Seed application may be performed by using an approved hand broadcaster or by broadcasting the seed by hand from a sack or other suitable container. Whichever means is used, the seed shall be uniformly applied at the rates suggested earlier. In the employment of this method, the seed and fertilizer shall be broadcast separately.

During or immediately following broadcast planting, nitrogen fertilizer should be applied to the areas being reclaimed at the rate of 10 to 15 pounds of nitrogen per acre as a starter fertilizer. Later in the growing season or in subsequent growing seasons, additional light applications of nitrogen fertilizer will undoubtedly be required. The timing and rate of fertilizer should be determined by the local manager, since it will have to be based upon local observation and experience. Applications of nitrogen fertilizer after the initial one should preferably be made by airplane, so that the surface of the reclaimed area is not disturbed thus making it subject to erosion. As stated earlier in the report, the selected mulch material should be applied immediately after planting the grasses, legume and shrubs, and fertilization. Following the mulching operation, the wind barriers (snow fences) should be installed.

Management of reclaimed area

After planting, fertilizing, mulching, and installation of wind barriers are completed, the entire reclaimed area should be enclosed with a barbed-wire fence which is designed and constructed in a manner to keep all livestock out of the area. The area should continue to be excluded from livestock grazing until the local manager determines that the planted vegetation is sufficiently developed and established to withstand grazing use without damaging the overall vegetative cover. In the event noxious weeds invade the rehabilitation site, the local manager should use acceptable methods of control to remove them from the plantings before desirable range plants are "crowded out" of the reclaimed area.

Glossary

Annual Plant (annuals), A plant that completes its life cycle and dies in 1 year or less.

Anticline, A fold of rock beds that is convex upward.

Aquifer, A water bearing formation through which water moves more readily than in adjacent formations with lower permeability.

Aspect, The direction toward which a slope faces. Exposure.

Attitude of Bedrock, A general term describing the relation of some directional features to a rock in a horizontal surface.

Available Nutrient, The part of the supply of a plant nutrient in the soil that can be taken up by plants at rates and in amounts significant to plant growth.

Available Water, The part of the water in the soil that can be taken up by plants at rates significant to their growth. Usable: obtainable.

Basin, A natural depression of strata containing a coal bed or other stratified deposit.

Bedrock, Any solid rock underlying soil, sand, clay, silt, and any other earthy materials.

Bench, The surface of an excavated area at some point between the material being mined and the original surface of the ground on which equipment can set, move or operate. A working road or base below a highwall as in contour stripping for coal.

Broadcast Seeding, Scattering seed on the surface of the soil. Contrast with drill seeding which places the seed in rows in the soil.

Buffer, Substances in soil or water that act chemically to resist changes in reaction or pH.

Calcareous Soil, Soil containing sufficient calcium carbonate (often with magnesium carbonate) to effervesce visibly when treated with cold 0.1 normal hydrochloric acid.

Capillary Water, The water held in the "capillary" or small pores of a soil, usually with tension greater than 60 centimeters of water. Much of this water is considered to be readily available to plants.

CFS, Cubic feet per second - measurement of water flow.

Channel Stabilization, Erosion prevention and stabilization of velocity distribution in a channel, using jetties, drops, revetments, vegetation, and other measures.

Clay (soils) (1) A mineral soil separate consisting of particles less than 0.002 millimeter is equivalent diameter. (2) A soil textural class. (3) (engineering) A fine-grained soil that has a high plasticity index in relation to the liquid limits.

Coal Horizon, The stratigraphic position where a coal should occur - generally used to signify the position that a coal should occupy but is absent.

Coal Seam, A layer, vein, or deposit of coal. A stratigraphic part of the earth's surface containing coal.

Coefficient, Permeability, The rate of flow of a fluid through a unit cross section of a porous mass under a unit hydraulic gradient, at a temperature of 60 degrees Fahrenheit. The standard coefficient of permeability used in the hydrologic work of the United States Geological Survey is defined as the rate of flow of water at 60 degrees Fahrenheit, in gallons or million gallons a day, through a cross section of 1 sq ft, under a hydraulic gradient of 100 percent.

Compaction, The closing of the pore spaces among the particles of soil and rock, generally caused by running heavy equipment over the area, as in the process of leveling the overburden material of strip mine banks.

Companion Crop (See Nurse Crop)

Concentration (water quality usage), The amount of a substance occurring in a given amount of water - common unit is parts per million (ppm) or milligrams per liter (mg/l).

Conifer, A tree belonging to the order Coniferae, usually evergreen with cones and needle-shaped or scale-like leaves and producing wood known commercially as "softwood."

Contour, An imaginary line connecting points of equal height above sea level as they follow the relief of the terrain.

Cool-Season Plant, A plant that makes its major growth during the cool portion of the year, primarily in the spring but in some localities in the winter.

Core Drilling, The process by which a cylindrical sample of rock and other strata is obtained through the use of a hollow drilling bit which cuts and retains a section of the rock or other strata penetrated.

Cut, Longitudinal excavation made by a strip-mining machine to remove overburden in a single progressive line from one side or end of the property.

Deciduous, Refers to a tree that sheds all its leaves every year at a certain season.

Deep Chiseling, Deep chiseling is a surface treatment that loosens compacted spoils. The process creates a series of parallel slots on the contour in the spoils surface which impedes water flows and markedly increases infiltration.

Density, Forage, The percent of ground surface which appears to be completely covered by vegetation when viewed directly from above.

Density, Stand, Density of stocking expressed in number of trees per acre.

Direct Seeding, A method of establishing a stand of vegetation by sowing seed on the ground surface.

Dissolved Solids, The difference between the total and suspended solids in water.

Disturbed Land, Land on which excavation has occurred or upon which overburden has been deposited, or both.

Diversion Ditch, A man-made waterway used for collection surface runoff on the uphill side of a mine in order to keep it out of the workings; a ditch designed to change the normal or actual course of water.

Dozer or Bulldozer, Tractor with a stell plate or blade mounted on the front end in such a manner that it can be used to cut into earth or other material and move said material primarily forward by pushing.

Drainage Plan, The proposed methods of collection, treatment and discharge of all waters within the affected drainage area as defined in the premining plan.

Ecology, The science that deals with the mutual relation of plants and animals to one another and to their environment.

Ecosystem, A total organic community in a defined area or time frame.

Effective Precipitation, That portion of total precipitation that becomes available for plant growth. It does not include precipitation lost to deep percolation below the root zone or to surface runoff.

Effluent, Any water flowing out of the ground or from an enclosure to the surface flow network.

Environment, All external conditions that may act upon an organism or soil to influence its development, including sunlight, temperature, moisture and other organisms.

Erodibility, The relative ease with which one soil erodes under specified conditions of slope as compared with other soils under the same conditions; this applies to both sheet and gully erosion.

Erosion, The wearing away of the land surface by running water, wind, ice, or other geological agents, including such processes as gravitational creep. Detachment and movement of soil or rock fragments by water, wind or ice, or gravity.

Essential Element (plant nutrition), A chemical element required for the normal growth of plants.

Evapotranspiration, A collective term meaning the loss of water to the atmosphere from both evaporation and transpiration by vegetation.

Excavation, The act of removing overburden material.

Fertilizer, Any natural or manufactured material added to the soil in order to supply one or more plant nutrients.

Fertilizer Grade, The guaranteed minimum analysis in whole numbers, in percent, of the major plant nutrient elements contained in a fertilizer material or in a mixed fertilizer. For example, a fertilizer with a grade of 20-10-5 contains 20 percent nitrogen (N), 10 percent available phosphoric acid (P_2O_5), and 5 percent

water-soluble potash (K_2O). Minor elements may also be included. Recent trends are to express the percentages in terms of the elemental fertilizer (nitgrogen (N), phosphorus (P), and potassium (K)).

Fill, Depth to which material is to be placed (filled) to bring the surface to a predetermined grade. Also, the material itself.

Flood, 10-Year, The flow of a stream which has been equaled or exceeded, on the average once in 10 years (or other designated period).

Food Annual, Annual - a flood equal to the mean of the discharges of all of the maximum annual floods during the period of record. Minimum - the smallest of the annual floods during the period of record.

Flood, Possible, Maximum, The largest flood that theoretically can occur at a given site during present geologic and climatic era, assuming simultaneous occurrence of all possible flood producing factors in the area.

Flood, Probable, The maximum flood for which there is a reasonable chance that it will occur on a given stream at a selected site. It is often assumed to be equal to the maximum flood observed in areas having the same or similar physiographic and meteorological characteristics. Such a flood would very likely be less than the maximum possible flood.

Forage, Unharvested plant material which can be used as feed by domestic animals. Forage may be grazed or cut for hay.

Forest Land, Land bearing a stand of trees at any age or stature, including seedlings and of species attaining a minimum of 6 feet average height at maturity or land from which such a stand has been removed but on which no other use has been substituted. The term is commonly limited to land not in farms; forests on farms are commonly called woodland or farm forests.

Fracture, The character or appearance of a freshly broken surface of any rock or mineral.

Germination, Sprouting; beginning of growth.

Gradation, A term used to describe the series of sizes into which a soil sample can be divided.

Grain Size, Physical size of soil particle, usually determined by either sieve or hydrometer analysis.

Ground Cover, Any living or dead vegetative material producing a protecting mat on or just above the soil surface.

Ground Water, Subsurface water occupying the saturation zone, from which wells and springs are fed. In a strict sense the term applies only to water below the water table. Also called plerotic water; phreatic water.

Growing Season, The season which in general, is warm enough for the growth of plants, the extreme average limits of duration being from the average date of the last killing frost in spring to that of the first killing frost in autumn. On the whole, however, the growing season is confined to that period of the year when the daily means are above 42 F.

Gully Erosion, Removal of soil by running water, with formation of deep channels that cannot be smoothed out completely by normal cultivation.

Habitat, The environment in which the life needs of a plant or animal are supplied.

Head (of Water), Water pressure expressed as the feet of elevation difference between the top of the water and the point at which the pressure is exerted.

Highwall, The unexcavated face of exposed overburden and coal in a surface mine or the face or bank on the uphill side of a contour strip mine excavation.

Hydrology, The science that relates to the water systems of the earth.

Hydroseeding, Dissemination of seed hydraulically in a water medium. Mulch, lime, and fertilizer can be incorporated into the sprayed mixture.

Impervious, Prohibits fluid flow.

Impoundment, A reservoir for collection of water. Collection of water by damming a stream or the like. Used in connection with the storage of tailings from a mine.

Infiltration, Water entering the ground water system through the land surface.

Intermittent Stream, A stream or portion of a stream that flows only in direct response to precipitation. It receives little or no water from springs and is dry for a large part of the year.

Land Classification, Classification of specific bodies of land according to their characteristics or to their capabilities for use. A use capability classification may be defined as one based on both physical and economic considerations according to their capabilities for man's use, with sufficient detail of categorical definition and cartographic (mapping) expression to indicate those differences significant to men.

Land Use Planning, The development of plans for the uses of land that, over long periods, will best serve the general welfare, together with the formulation of ways and means for achieving such uses.

Leaching, The removal of materials in solution by the passage of water through soil.

Leachate, Liquid that has percolated through a medium and has extracted dissolved or suspended materials from it.

Legume, A member of the legume or pulse family, leguminosae. One of the most important and widely distributed plant families. Includes many valuable food and forage species, such as the peas, beans, peanuts, clovers, alfalfas, sweet clovers, lespedezas, vetches and kudzu. Practically all legumes are nitrogen-fixing plants.

Lime, Lime, from the strictly chemical standpoint, refers to only one compound, calcium oxide (CaO); however, the term lime is commonly used in agriculture to include a great variety of materials which are usually composed of the oxide, hydroxide, or carbonate of calcium or of calcium and magnesium. The most commonly used forms of agricultural line are ground limestone, marl, and oyster shells (carbonates), hydrated lime (hydroxides), and burnt lime (oxides).

- Quicklime - limestone + heat (calcined) CaO
- Hydrated lime - quicklime + H_2O $Ca(OH)_2$
- Slaked lime - same as hydrated but slaking equipment is used for adding water
- Milk of lime - water mixture containing lime in solution + lime in suspension

Lime Requirement, The amount of standard ground limestone required to bring a 6.6 inch layer of an acre (about 2 million pounds of mineral soils) of acid soil to some specific lesser degree of acidity, usually to slightly or very slightly acid. In common practice, lime requirements are given in tons per acre of nearly pure limestone, ground finely enough so that all of it passes a 10-mesh screen and at least half of it passes a 100-mesh screen.

Micro-Climate, A local climatic condition near the ground resulting from modification of relief, exposure, or cover.

Micro-Nutrients, Nutrients in only small, trace, or minute amounts.

Mine Drainage, Any water forming on or discharging from a mining operation. May be alkaline or acid in nature.

Mined-Land, Land with new surface characteristics due to the removal of mineable commodity by surface mining methods and subsequent surface reclamation.

Mulch, A natural or artificial layer of plant residue or other materials placed on the soil surface to protect seeds, to prevent blowing, to retain soil moisture, to curtail erosion, and to modify soil temperature.

Natural Revegetation, Natural reestablishment of plants; propagation of new plants over an area by natural processes.

Natural Seeding (Volunteer), Natural distribution of seed over an area.

Neutralization, The process of adding an acid or alkaline material to water or soil to adjust its pH to a neutral position.

Neutral Soil, A soil in which the surface layer, at least to normal plow depth, is neither acid nor alkaline in reaction. For most practical purposes, soil with a pH ranging from 6.6 through 7.3.

Nitrogen Fixation, The conversion of atmospheric (free) nitrogen to nitrogen compounds. In soils the assimilation of free nitrogen from the air by soil organisms (making the nitrogen eventually available to plants). Nitrogen fixing organisms associated with plants such as the legumes are called symbiotic; those not definitely associated with plants are called monsymbiotic.

Nurse Crop, A planting or seeding that is used to protect a tender species during its early life. A nurse crop is usually temporary and gives way to the permanent crop. Sometimes referred to as a companion crop.

Nutrients, Any element taken into a plant that is essential to its growth.

Operation, All of the premises, facilities, railroad loops, roads, and equipment used in the process of extracting and removing a mineral commodity from a mineral commodity from a designated surface mine or in the determination of the location, quality, and quantity of a natural mineral deposit.

Overburden, The earth, rock, and other materials which lie above the coal.

Parent Material, The unconsolidated mass of rock material (or pest) from which the soil profile develops.

Percolation, Downward movement of water through soils.

Permeability, The measure of the capacity for transmitting a fluid through the substance.

pH, The symbol or term refers to a scale commonly used to express the degrees of acidity or alkalinity. On this scale pH of 1 is the strongest acid, pH of 14 is the strongest alkali, pH of 7 is the point of neutrality at which there is neither acidity or alkalinity. pH is not a measure of the weight of acide or alkali contained in or available in a given volume.

Pit, Used in reference to a specifically describable area of open cut mining. May be used to refer to only that part of the open cut mining area from which coal is being actively removed or may refer to the entire contiguous mined area.

Pit, Borrow, A bank or pit from which earth is taken for use in filling or embanking.

Pollution, Environmental degradation resulting from man's activities or natural events.

Pond, A body of water of limited size either naturally or artificially confined and usually smaller than a lake.

Porosity - Effective, The ratio, usually expressed in percentage of (a) the volume of water or other liquid which a given volume of rock or soil, after being saturated with the liquid, will yield under any specified hydraulic conditions, to (b) the total volume of soil or rock.

Rain (1) Heavy--Rain which is falling at the time of observation with an intensity in excess of 0.30 in. per hr (over 0.03 inch in 6 min). (2) Light--Rain which is falling at the time of observation with an intensity of between a trace and 0.10 in. per hr (0.01 inch in 6 min). (3) Moderate--Rain which is falling at the time of observation with an intensity of between 0.11 in. per hr (0.01+ inch in 6 min) and 0.30 in. per hr (0.03 inch in 6 min).

Range Land where the potential natural vegetation is predominantly grasses, grasslike plants, forbs, or shrubs, where natural herbivory was an important influence in its precivilization state, and that is more suitable for management by ecological rather than agronomic principles.

Rate, Percolation, The rate, usually expressed as a velocity, at which water moves through saturated granular material. The term is also applied to quantity per unit of time of such movement, and has been used erroneously to designate infiltration rate or infiltration capacity.

Reclamation, The process of reconverting mined land to its former or other productive uses.

Recreation Land, Land and water used, or usable primarily as sites for outdoor recreation facilities and activities.

Reforestation, The natural or artificial restocking of an area with forest trees.

Regrading, The movement of earth over a depression to change the shape of the land surface. A finer form of backfilling.

Rehabilitation, Implies that the land will be returned to a form and productivity in conformity with a prior land use plan, including a stable ecological state that does not contribute substantially to environmental deterioration and is consistent with surrounding aesthetic values.

Restoration, The process of restoring site conditions as they were before the land disturbance.

Revegetation, Plants or growth which replaces original ground cover following land disturbance.

Ripping, The act of breaking, with a tractor-drawn ripper or long angled steel tooth, compacted soils or rock into pieces small enough to be economically excavated or moved by other equipment as a scraper or dozer.

Runoff, That portion of the rainfall that is not absorbed by the deep strata: is utilized by vegetation or lost by evaporation or may find its way into streams as surface flow.

Runoff Volume, The total quantity or volume of runoff during a specified time. It may be expressed in acre-feet, in inches depth on the drainage area, or in other units.

Saline-Alkali Soil, A soil having a combination of a harmful quantity of salts and either a high degree of alkalinity or a high amount of exchangeable sodium, or both, so distributed in the soil profile that the growth of most crop plants is less than normal.

Saline Soil, A soil containing enough soluble salts to impair its productivity for plants but not containing an excess of exchangeable sodium.

Sandstone, A cemented or otherwise compacted detrital sediment composed predominantly of quartz grains, the grades of the latter being those of sand.

Saturation, Completely filled; a condition reached by a material, whether it be in solid, gaseous, or liquid state, which holds another material within itself in a given state in an amount such that no more of such material can be held within it in the same state. The material is then said to be saturated or in a condition of saturation.

Seam, A stratum or bed of coal.

Sediment, Solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water, gravity, or ice and has come to rest on the earth's surface either above or below sea level.

Sediment Basin, A reservoir for the confinement and retention of silt, gravel, rock, or other debris from a sediment-producing area.

Seedbed, The soil prepared by natural or artificial means to promote the germination of seed and the growth of seedlings.

Seep, A more or less poorly defined area where water oozes from the earth in small quantities.

Shale, Sedimentary or stratified rock structure generally formed by the consolidation of clay or clay-like material.

Side Slopes, The slope of the sides of a canal, dam, or embankment. It is customary to name the horizontal distance first as 1.5 to 1.0 or frequently 1-1/2:1 meaning a horizontal distance of 1.5 feet to 1 foot vertical.

Silt, Small mineral soil grains the particles of which range in diameter from 0.05 to 0.002 mm (or 0.02-0.002 mm in the international system).

Slope Stability, The resistance of any inclined surface, as the wall of an open pit or cut, to failure by sliding or collapsing.

Soil (See Acid Soil and Alkaline Soil) Surface layer of the earth, ranging in thickness from a few inches to several feet composed of finely divided rock debris mixed with decomposing vegetative and animal matter which is capable of supporting plant growth.

Soil Condition, Any material added to a soil for the purpose of improving its physical condition.

Soil Conserving Crops, Crops that prevent or retard erosion and maintain or replenish rather than deplete soil organic matter.

Soil Porosity, The degree to which the soil mass is permeated with pores or cavities. It is expressed as the percentage of the whole volume of the soil which is unoccupied by solid particles.

Soil Profile, A vertical section of the soil through all its horizons and extending into the parent material.

Soil Structure, The combination or arrangement of primary soil particles into secondary particles, units, or beds.

Solum, The upper part of a soil profile, above the parent material, in which the processes of soil formation are active. The solum in mature soils includes the A and B horizons. Usually the characteristics of the material in these horizons are quite unlike those of the underlying parent material. The living roots and other plant life and animal life characteristic of the soil are largely confined to the solum.

Spoil, The overburden or non-coal material removed in gaining access to the coal or mineral material in surface mining.

Spoil Bank (Spoil Pile), Area created by the deposited spoil or overburden material prior to backfilling. Also called cast overburden.

Stabiline, Settle, fix in place, non-moving, usually accomplished on overburden by planting trees, shrubs, or grasses, or by mechanical compaction or aging.

Stratified, Composed of, or arranged in, strata or layers, as stratified alluvium. The term is applied to geological materials. Those layers in soils that are produced by the processes of soil formation are called horizons, while those inherited from parent material are called strata.

Strike, The coarse or bearing of the outcrop of an inclined bed or structure on a level surface. Also the direction or bearing of a horizontal line in the plane of an inclined stratum, joint, fault, cleavage plane, or other structural plane. It is always perpendicular to the dip direction.

Strip, To mine a deposit by first taking off the overlying burden.

Strip Mine, Refers to a procedure of mining which entails the complete removal of all material from over the product to be mined in a series of rows or strips; also referred to as "open cut," "open pit," or "surface mine."

Strip Mining (See Surface Mining)

Stripping, The removal of earth or non-ore rock materials as required to gain access to the ore or mineral materials wanted. The process of removing overburden or waste material in a surface mining operation.

Subsoil, The B horizon of soils with distinct profiles. In soils with weak profile development, the subsoil can be defined as the soil below the plowed soil (or its equivalent of surface soil) in which roots normally grow. Although a common term, it cannot be defined accurately. It has been carried over from early days when "soil" was conceived only as the plowed soil and that under it as "subsoil."

Surface Mining, Mining method whereby the overlying materials are removed to expose the mineral for extraction.

Surface Soil, That part of the upper soil of arable soils commonly stirred by tillage implements or an equivalent depth (5 to 8 inches) in non-arable soils.

Suspended Solids, Sediment which is in suspension in water but which will physically settle out under quiescent conditions (as differentiated from dissolved material).

Terrace, Sloping ground cut into a succession of benches and steep inclines for purposes of cultivation or to control surface runoff and minimize soil erosion.

Terraced Slope, A slope that is intersected by one or more terraces.

Texture, The character, arrangement and mode of aggregation of particles which make up the earth's surface.

Tilth, The physical condition of a soil in respect to its fitness for the growth of a specified plant.

Topography, The shape of the ground surface, such as hills, mountains or plains. Steep topography indicates steep slopes or hilly land; flat topography indicates flat land with minor undulations and gentle slopes.

Topsoil, Presumed fertile soil material---used as a top dressing. Distinction has been made among synthetic, weathered, and geologic topsoil. Synthetic topsoil can include sand and stone chips as well as fly ash, sawdust, or manure not usually a part of geological soil and rock. Weathered topsoil is the natural top-dressing material that has been subjected to weathering throughout geologic time.

Toxic Spoil (See also Acid Spoil), Includes acid spoil with pH below 4.0. Also refers to spoil having amounts of minerals such as aluminum, manganese, and iron that adversely affect plant growth.

Transpiration, The normal loss of water vapor to the atmosphere from plants.

Unconsolidated (soil material), Soil material in a form of loose aggregation.

Vegetation, General term including grasses, legumes, shrubs, trees naturally occurring and planted intentionally.

Vegetative Cover, The entire vegetative canopy on an area.

Volunteer, Springing up spontaneously or without being planted; a volunteer plant.

Watershed Area, Surface region or area contributing to the supply of a stream or lake, drainage area, drainage basin, catchment area.

Water, Subsurface, Water that occurs beneath the surface of the earth. It may be liquid, solid or gaseous state. It comprises suspended water and ground water.

Weathering, The group of processes, such as chemical action of air and rainwater and of plants and bacteria and the mechanical action of changes in temperature, whereby rocks, on exposure to the weather, change in character, decay, and finally crumble.

Wildlife, Undomesticated vertebrate animals, except fish, considered collectively.

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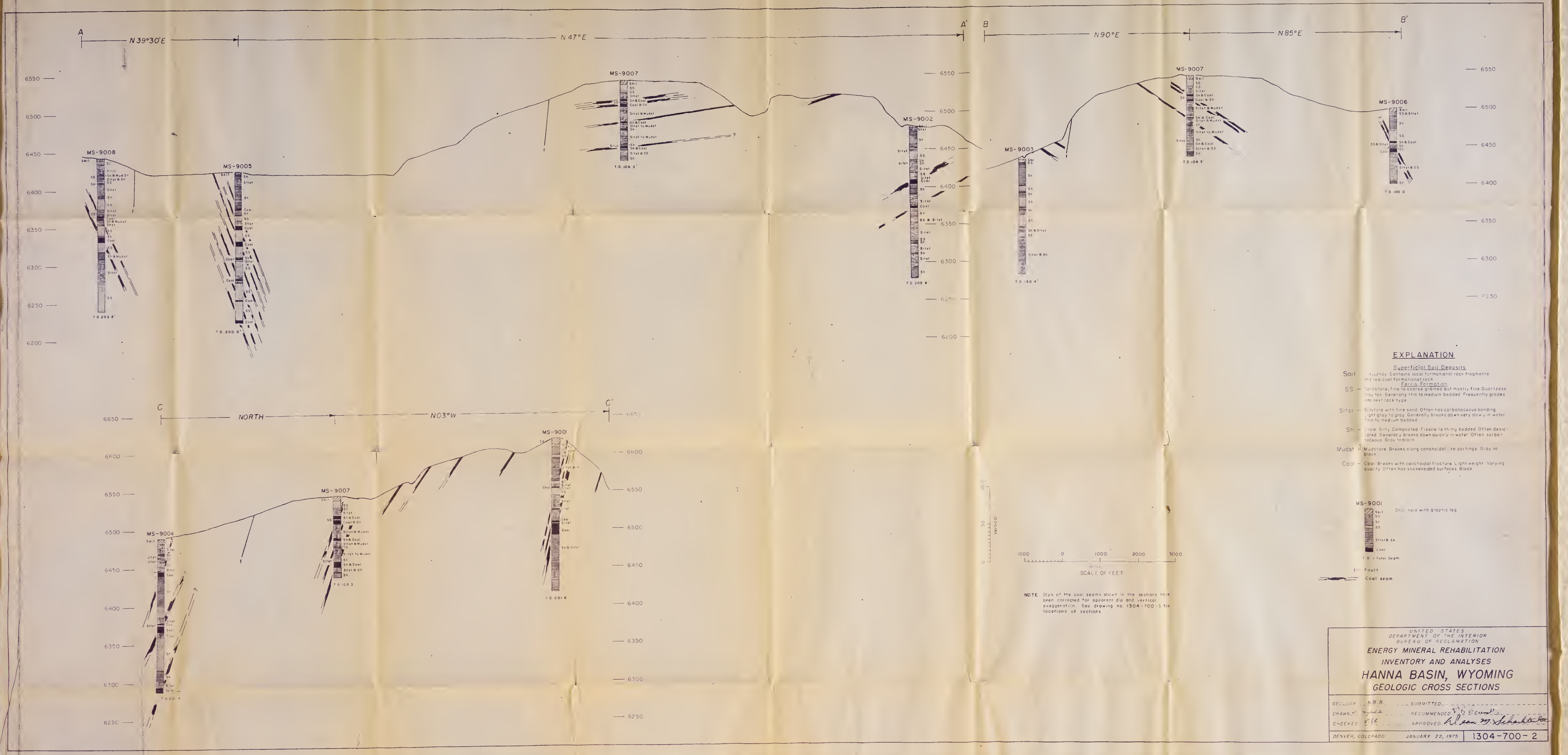
A
N39°30'E
N47°E
A'
B
N90°E
N85°E
B'
MS-9008
MS-9005
MS-9007
MS-9002
MS-9003
MS-9006
T.D. 203.8'
T.D. 200.0'
T.D. 106.3'
T.D. 200.8'
T.D. 150.4'
T.D. 100.0
6550
6500
6450
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6350
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6250
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C
NORTH
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MS-9004
MS-9007
MS-9001
6650
6600
T.D. 106.3
T.D. 201.8
EXPLANATION
Superficial Soil Deposits
Soil — Silt, sandy. Contains local formational rock fragments and residual formational rock
Ferris Formation
SS — Sandstone, fine to coarse grained but mostly fine. Quartzose. Gray tan. Generally thin to medium bedded. Frequently grades into next rock type
Sltst — Siltstone with fine sand. Often has carbonaceous banding. Light gray to gray. Generally breaks down very slowly in water. Thin to medium bedded
Sh — Shale. Silty. Compacted. Fissile to thinly bedded. Often desiccated. Generally breaks down quickly in water. Often carbonaceous. Gray to black
Mudst — Mudstone. Breaks along conchoidal like partings. Gray to black
Coal — Coal. Breaks with conchoidal fracture. Light weight. Varying quality. Often has slickensided surfaces. Black
MS-9001
Soil
SS
Sh
SS
Sltst & Sh
Coal
Drill hole with graphic log
T.D. = Total Depth
Fault
Coal seam
50
Vertical
0
1000
0
1000
2000
3000
Horiz.
SCALE OF FEET
NOTE. Dips of the coal seams shown in the sections have been corrected for apparent dip and vertical exaggeration. See drawing no. 1304-700-3 for locations of sections
UNITED STATES
DEPARTMENT OF THE INTERIOR
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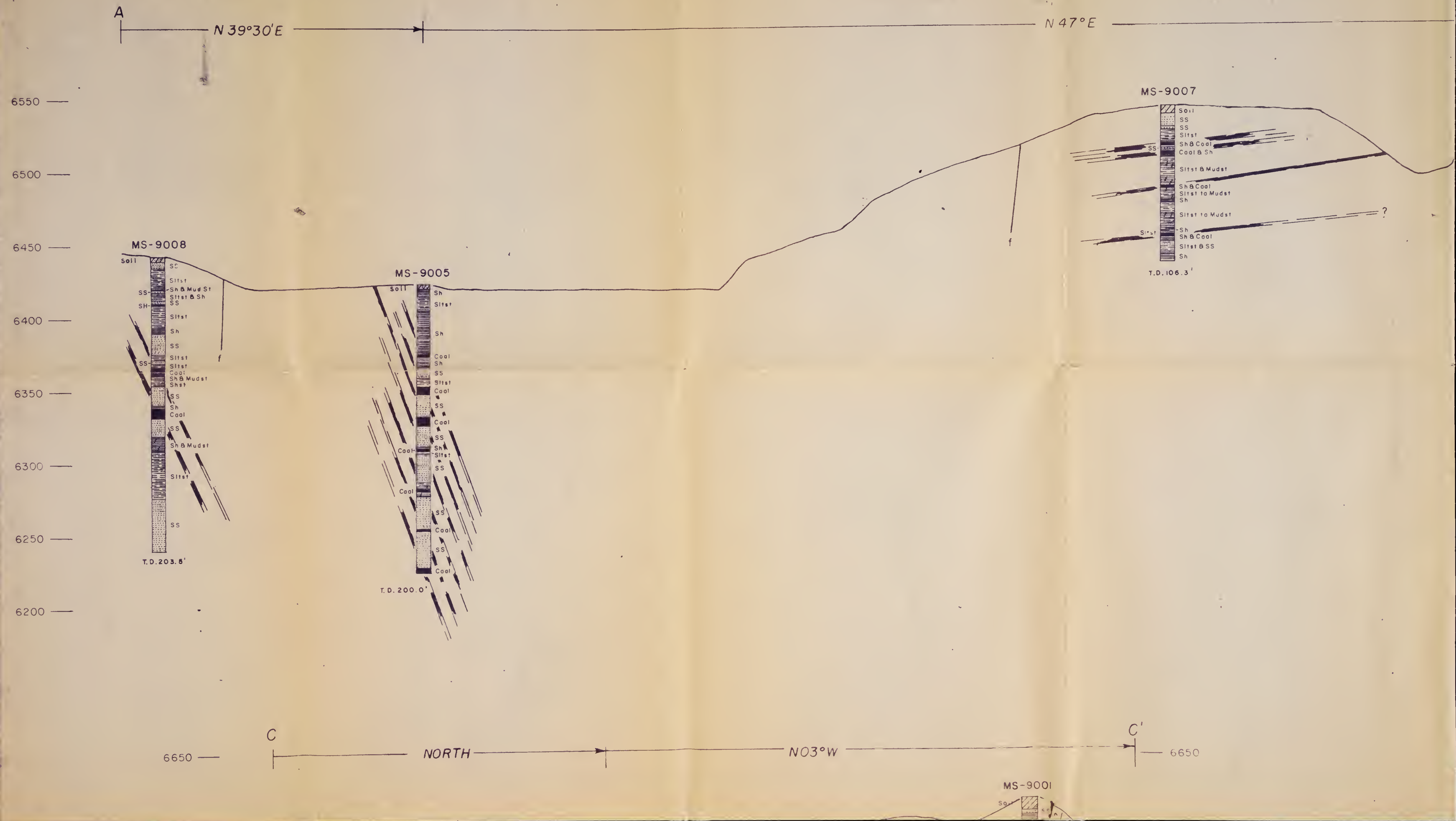
ENERGY MINERAL REHABILITATION
INVENTORY AND ANALYSES
HANNA BASIN, WYOMING
GEOLOGIC CROSS SECTIONS
GEOLOGY N.B.B.
SUBMITTED
DRAWN
RECOMMENDED
CHECKED NBB
APPROVED
DENVER, COLORADO
JANUARY 22, 1975
1304-700-2


A
N 39°30'E
N 47°E
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MS-9008
Soil
SS
Sltst
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Soil
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SS
Coal
SS
Coal
T.D. 200.0'
MS-9007
Soil
SS
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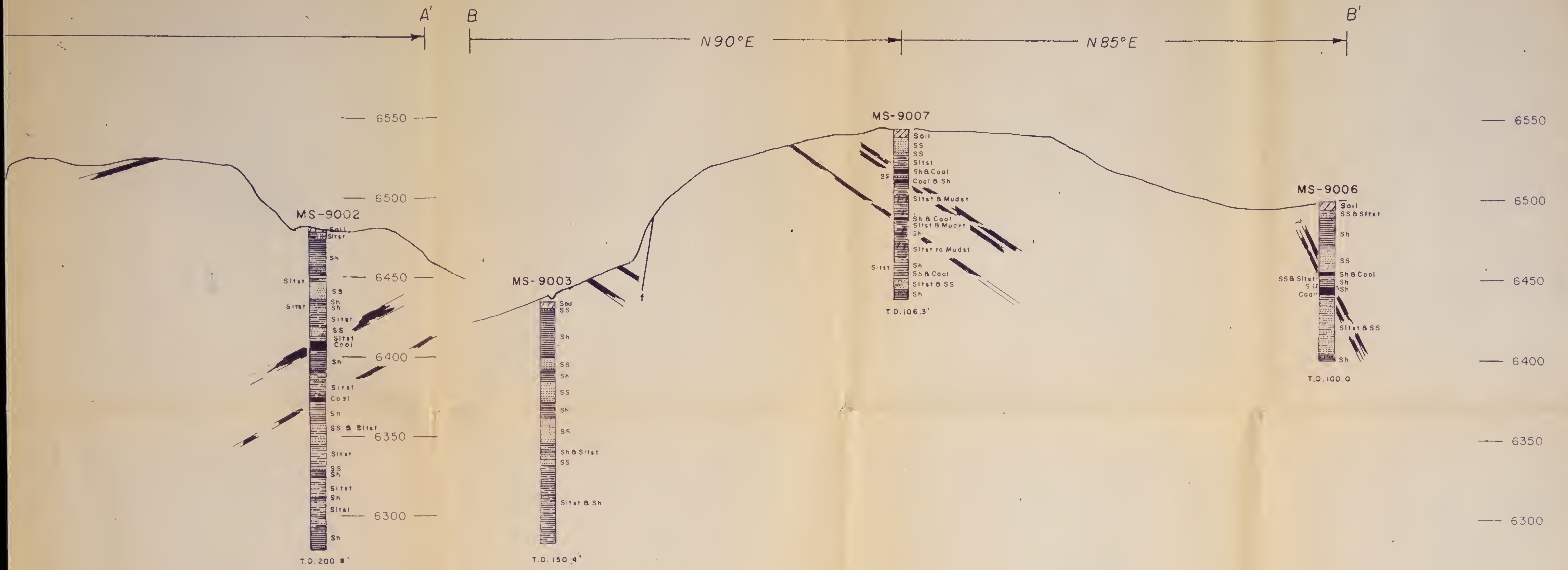
MS-9001



EXPLANATION

Superficial Soil Deposits

Soil – Silt, sandy Contains local formational rock fragments and residual formational rock.

Ferris Formation

SS – Sandstone, fine to coarse grained but mostly fine. Quartzose. Gray tan. Generally thin to medium bedded. Frequently grades into next rock type.

Sltst – Siltstone with fine sand. Often has carbonaceous banding. Light gray to gray Generally breaks down very slowly in water. Thin to medium bedded.

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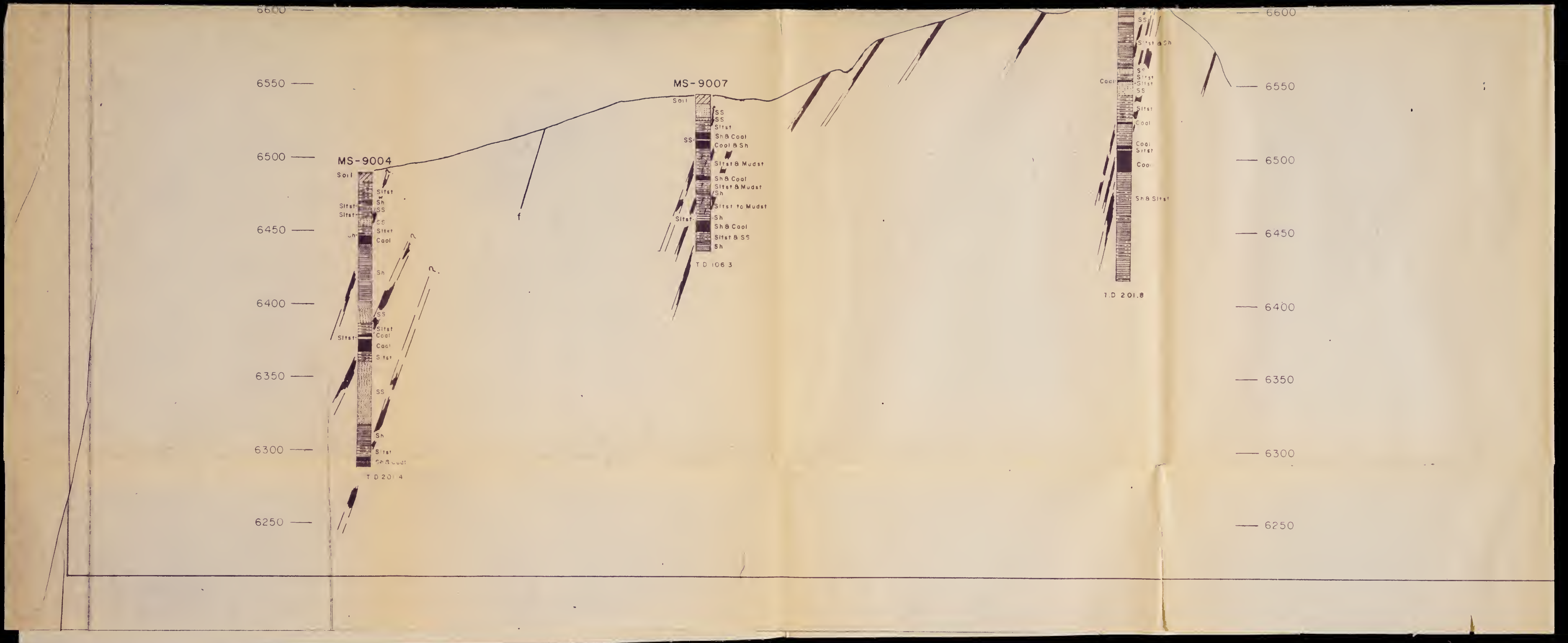

6600
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6400
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6300
6250
MS-9004
Soil
Sltst
Sh
SS
Sltst
Sltst
SS
Sltst
Sh
Coal
Sh
SS
Sltst
Coal
Sltst
Coal
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Sh
Sltst
T.D. 201.4
f
MS-9007
Soil
SS
SS
Sltst
SS
Sh & Coal
Coal & Sh
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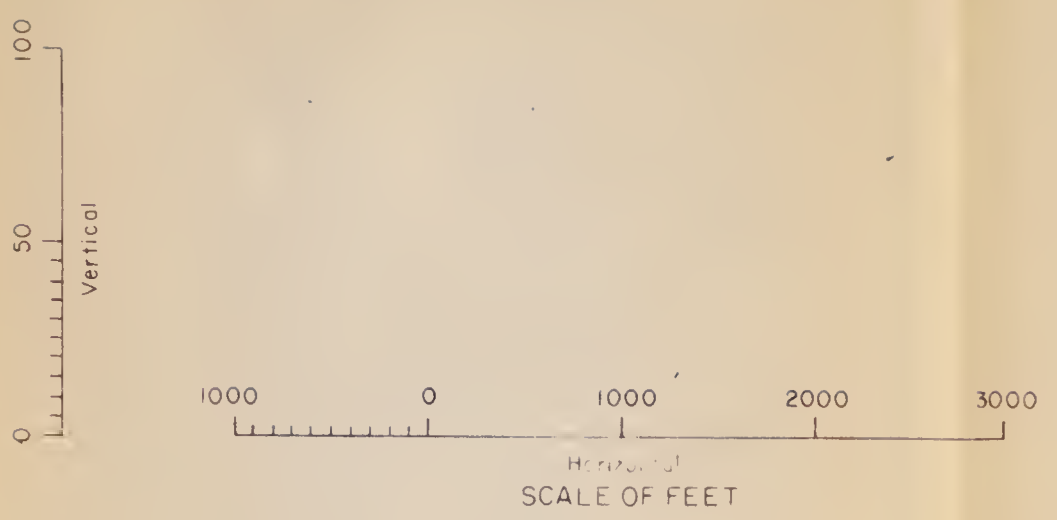
T.D. 201.8
6600
6550
6500
6450
6400
6350
6300
6250

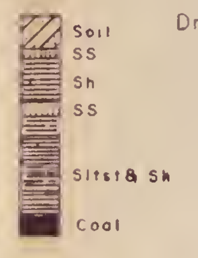
Mudst — Mudstone. Breaks along conchoidal like partings. Gray to black.

Coal — Coal. Breaks with conchoidal fracture. Light weight. Varying quality. Often has slickensided surfaces. Black.



NOTE: Dips of the coal seams shown in the sections have been corrected for apparent dip and vertical exaggeration. See drawing no. 1304-700-3 for locations of sections.

MS-9001



Drill hole with graphic log.

T.D. = Total Depth

f — Fault

Coal seam

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ENERGY MINERAL REHABILITATION
INVENTORY AND ANALYSES

HANNA BASIN, WYOMING

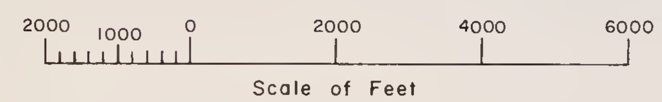
GEOLOGIC CROSS SECTIONS

GEOLOGY N.B.B.	SUBMITTED
DRAWN D.C. Michalek	RECOMMENDED N.B. Bennett
CHECKED NBB	APPROVED Dean M. Schachtele
DENVER, COLORADO JANUARY 22, 1975	1304-700-2

EXPLANATION

Qt	Terrace gravel
Tf	Ferris Formation -- light colored or dark gray carbonaceous shale: buff to brown sandstone: pockets, lenses, and thin beds of conglomerate in lower part: numerous beds of coal.
	Outcrop of coal bed (line dashed where outcrop is uncertain).
	Contact of lithologic units.
	Fault (line dashed where uncertain).
6°	Strike and dip of strata.
MS-9002	Location of drill hole.

Note: geology based on U. S. G. S. Bulletin 804, "Geology and Coal and Oil Resources of the Hanna and Carbon Basins, Carbon Co., Wyoming" by C. E. Dobbin, C. F. Bowen, and H. W. Hoots, 1929. See Drawing 1304-700-2 for Geologic Section A-A', B-B', and C-C'.



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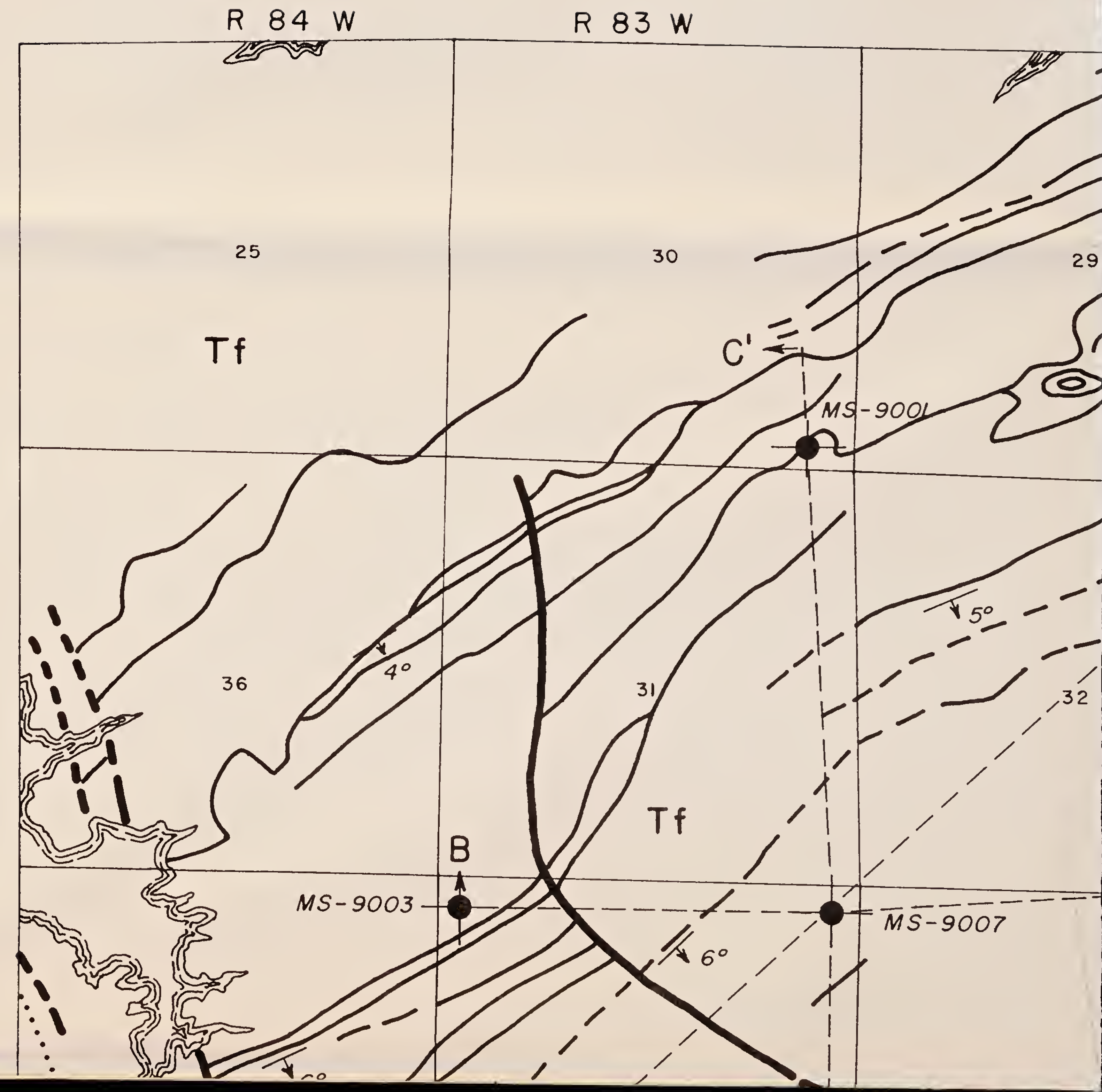
ENERGY MINERAL REHABILITATION
INVENTORY AND ANALYSES

HANNA BASIN, WYOMING
SURFACE GEOLOGIC MAP

DRAWN E.H.F	SUBMITTED
TRACED	RECOMMENDED [signature]
CHECKED [initials]	APPROVED [signature]

DENVER, COLORADO — JANUARY 31, 1975 — 1304-700-3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R 83 W
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4°
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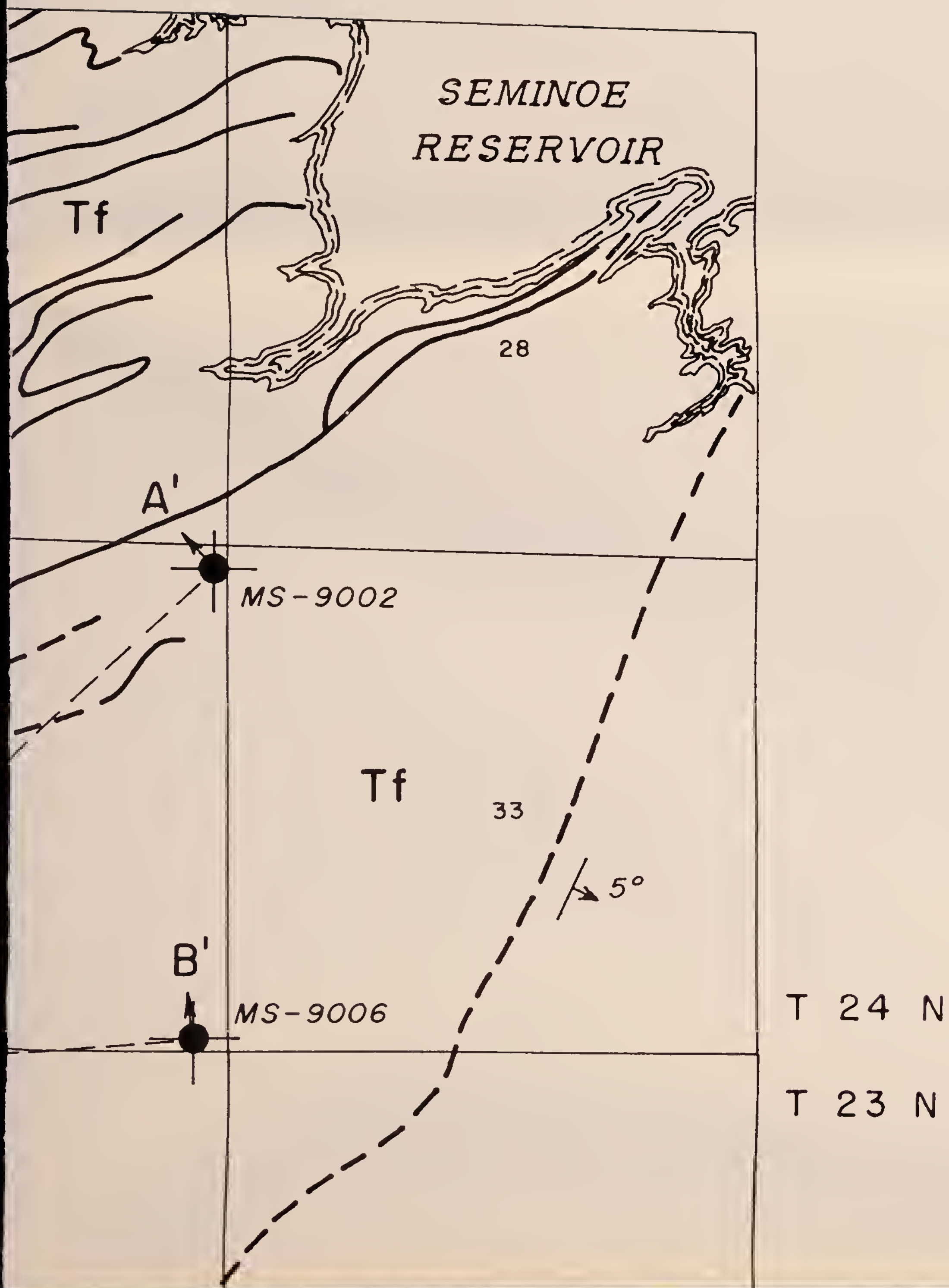
Tf
B
MS-9003
MS-9007
6°



EXPLANATION

Qt — Terrace gravel

Tf — Ferris Formation -- light colored or dark gray carbonaceous shale: buff to brown sandstone: pockets, lenses, and thin beds of conglomerate in lower part: numerous beds of coal.

Outcrop of coal bed (line dashed where outcrop is uncertain).

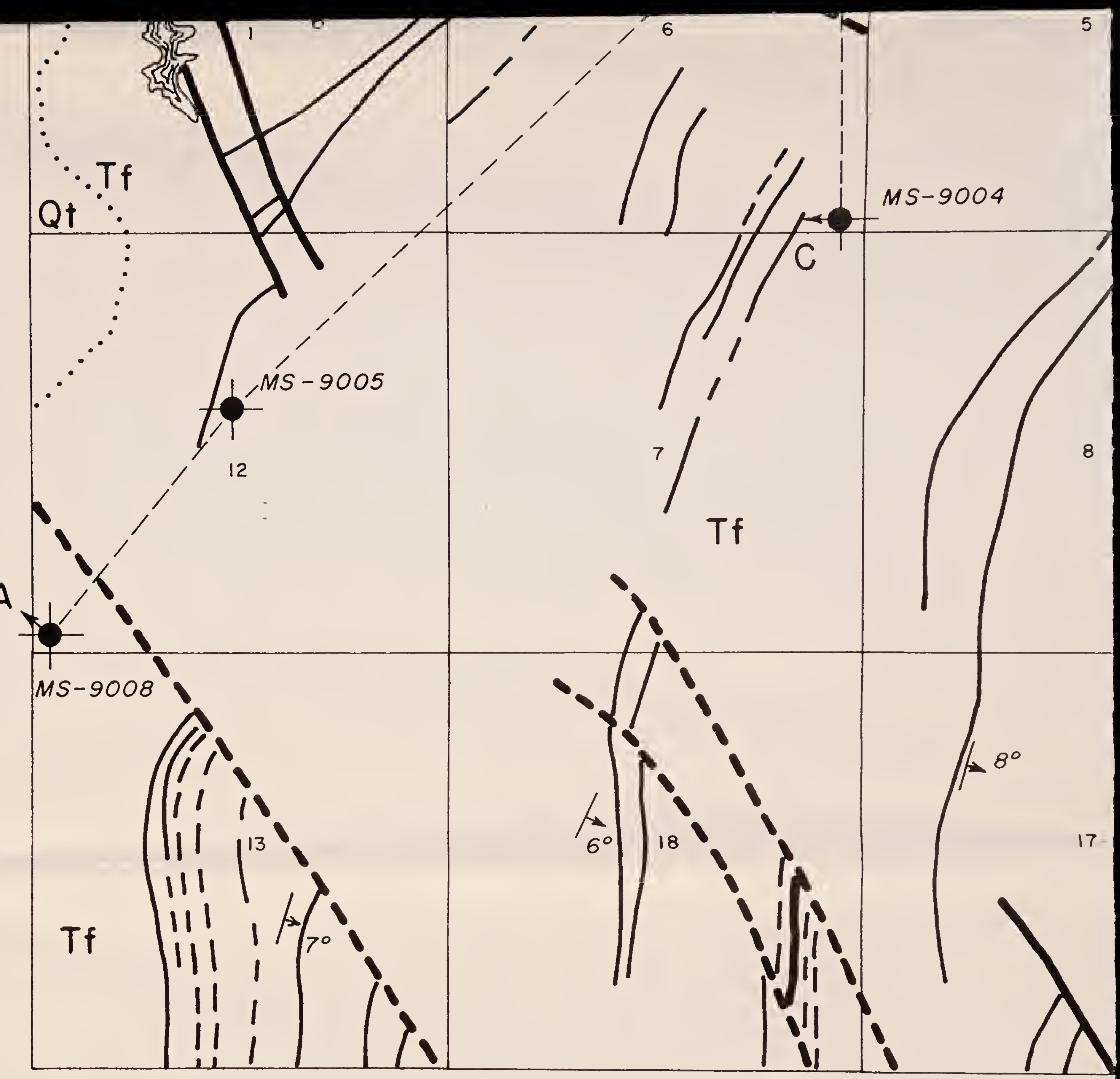
Contact of lithologic units.

Fault (line dashed where uncertain).

8° — Strike and dip of strata.

MS-9002 — Location of drill hole.

Note: geology based on U. S. G. S. Bulletin 804, "Geology and Coal and Oil Resources of the Hanna and Carbon Basins, Carbon Co., Wyoming" by C. E. Dobbin, C. F. Bowen, and H. W. Hoots, 1929. See Drawing 1304-700-2 for Geologic Section A-A', B-B', and C-C'.



Qt
Tf
MS-9004
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7
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A
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7°
6°
18
8°
17
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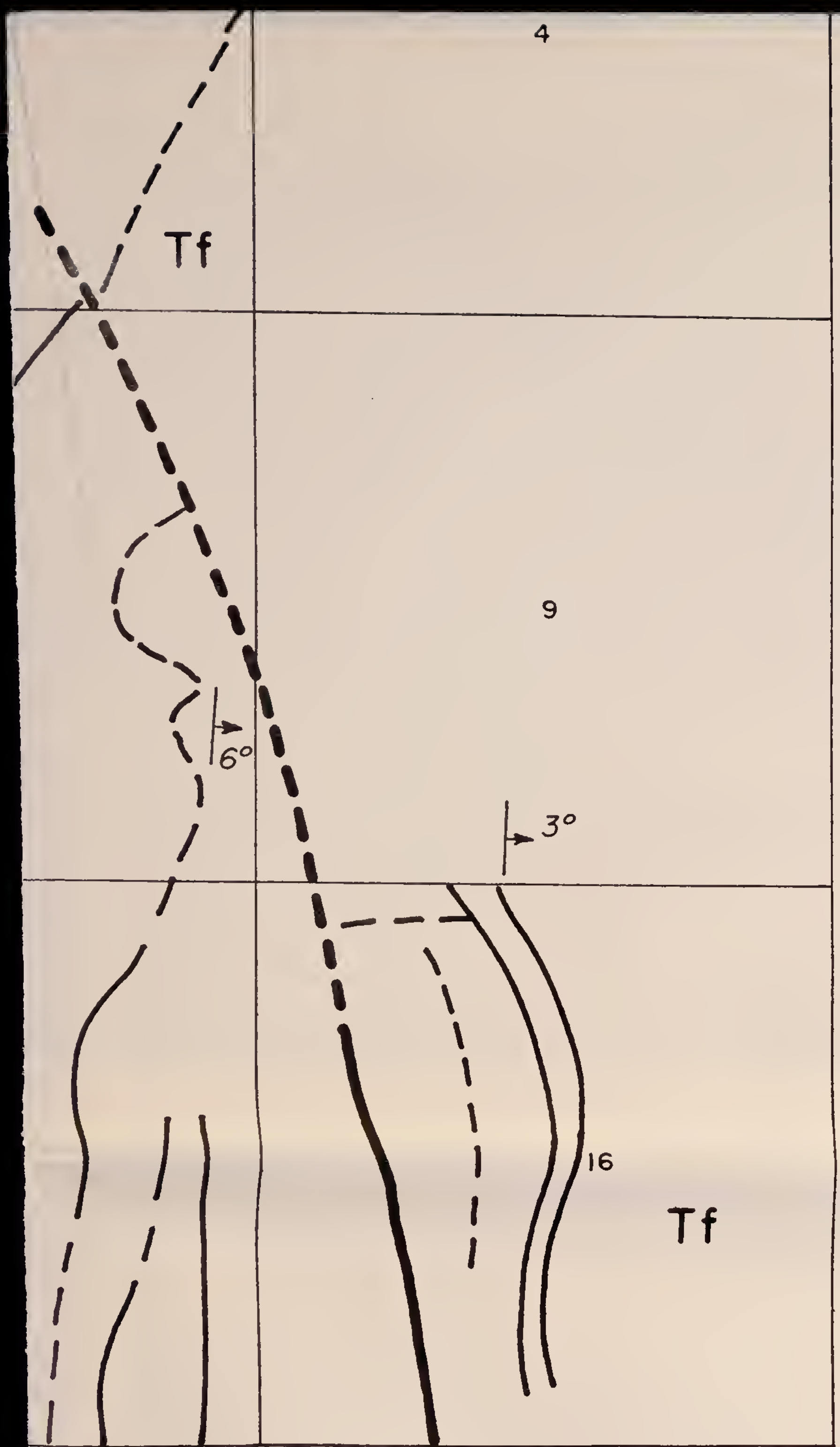

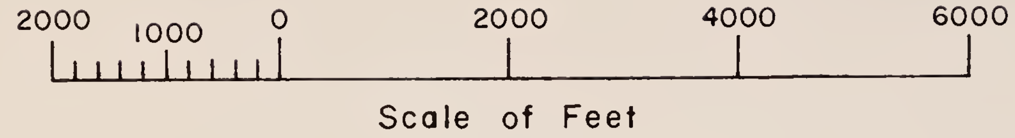

ALWAYS THINK **SAFETY**

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

ENERGY MINERAL REHABILITATION

INVENTORY AND ANALYSES

HANNA BASIN, WYOMING
SURFACE GEOLOGIC MAP

DRAWN E.H.F	SUBMITTED
TRACED	RECOMMENDED J.B. Bennett III
CHECKED J.B.B.	APPROVED Dean M. Schachterle
DENVER, COLORADO JANUARY 31, 1975	1304-700-3

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SEMINOE DAM SE QUADRANGLE

WYOMING CARBON CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)

Mapped, edited, and published by the Geological Survey as part of the Department of the Interior program for the development of the Missouri River Basin

Control by USGS and USC&GS

Topography from aerial photographs by multiplex methods
Aerial photographs taken 1949. Field check 1953

Polyconic projection. 1927 North American datum
10,000-foot grid based on Wyoming coordinate system, east central zone

Dashed land lines indicate approximate locations

1000-meter Universal Transverse Mercator grid ticks, zone 13, shown in blue

GN MN
1°13′ 22 MILS
15° 267 MILS

UTM GRID AND 1953 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24000

1 ½ 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 .5 0 1 KILOMETER

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR WASHINGTON, D. C. 20242
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

WYOMING
QUADRANGLE LOCATION

ROAD CLASSIFICATION

Heavy-duty		Light-duty	
Medium-duty		Unimproved dirt	
U. S. Route		State Route	

SEMINOE DAM SE, WYO.
N4200—W10645/7.5

1953

AMS 4668 III SE–SERIES V874

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SEMINOE DAM SE QUADRANGLE
WYOMING–CARBON CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)

(WALCOTT 1:62 500)
4667 IV

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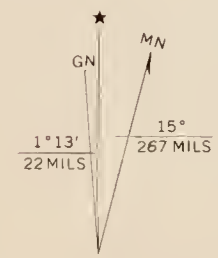
Control by USGS and USC&GS

Topography from aerial photographs by multiplex methods
Aerial photographs taken 1949. Field check 1953

Polyconic projection. 1927 North American datum
10,000-foot grid based on Wyoming coordinate system, east central zone

Dashed land lines indicate approximate locations

1000-meter Universal Transverse Mercator grid ticks, zone 13, shown in blue



UTM GRID AND 1953 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

SCALE

1 ½

1000 0 1000 2000 30

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DATUM IS ME

THIS MAP COMPLIES WITH NATIO
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVE
A FOLDER DESCRIBING TOPOGRAPHIC MAPS

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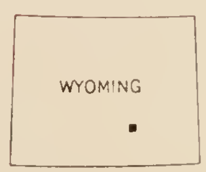


QUADRANGLE LOCATION

ROAD CLASSIFICATION

Heavy-duty — Light-duty

Medium-duty — Unimproved dirt

U. S. Route — State Route

SEMINOE DAM SE, WYO.

N4200—W10645/7.5

1953

AMS 4668 III SE-SERIES V874

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PATS BOTTOM QUADRANGLE
WYOMING—CARBON CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
NE/4 WALCOTT 15' QUADRANGLE

Mapped, edited, and published by the Geological Survey

Control by USGS and USC&GS

Topography by photogrammetric methods from aerial photographs taken 1970. Field checked 1971

Projection and 10,000-foot grid ticks: Wyoming coordinate system, east central zone (transverse Mercator) 1000-meter Universal Transverse Mercator grid ticks, zone 13, shown in blue. 1927 North American datum

Fine red dashed lines indicate selected fence lines

Underwater contours taken from U. S. Bureau of Reclamation maps dated 1950

UTM GRID AND 1971 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U.S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

WYOMING
QUADRANGLE LOCATION

ROAD CLASSIFICATION

Primary highway, hard surface
Light-duty road, hard or improved surface
Secondary highway, hard surface
Unimproved road
Interstate Route
U S Route
State Route

PATS BOTTOM, WYO.
NE/4 WALCOTT 15' QUADRANGLE
N4152.5—W10645/7.5

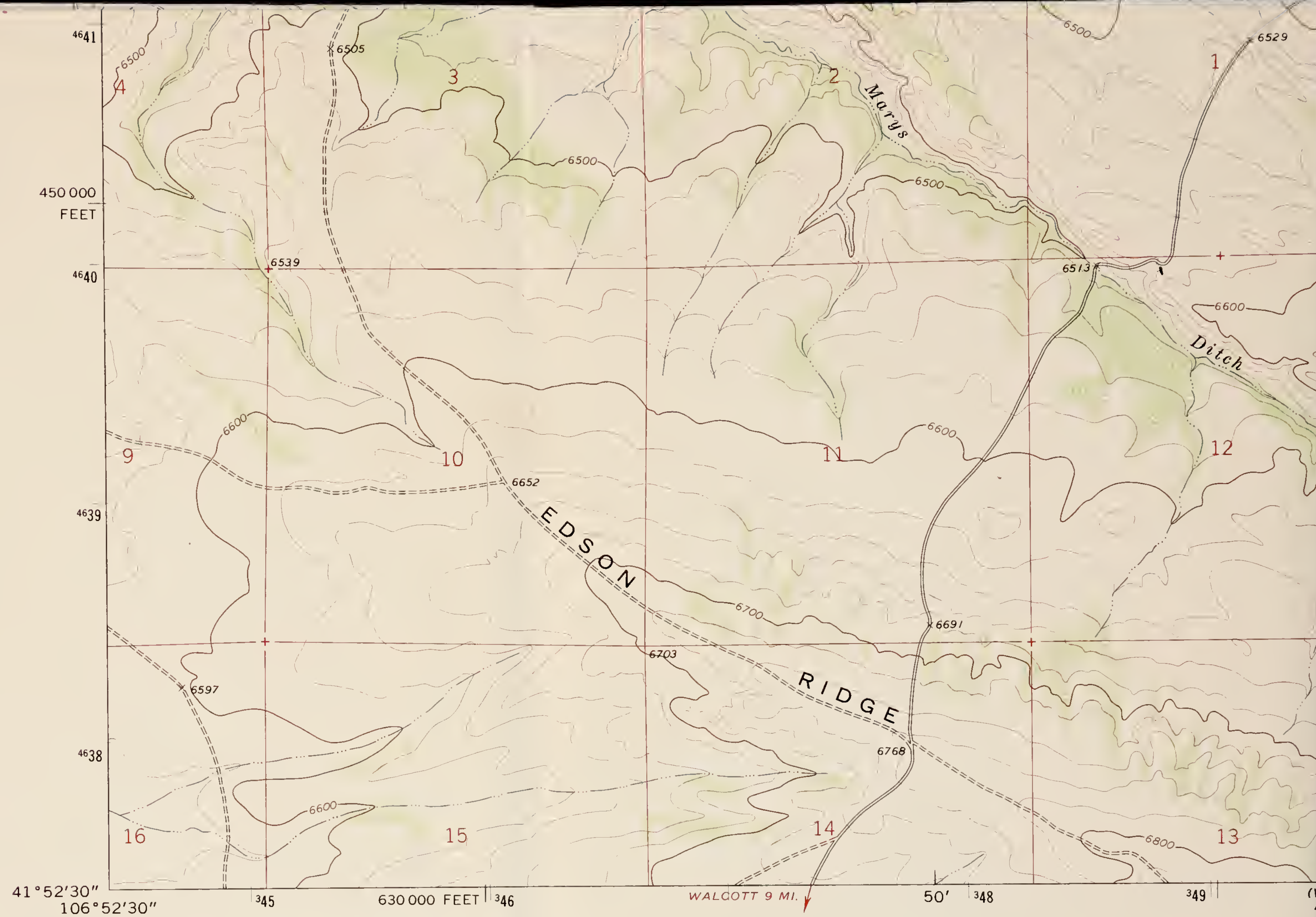
1971

AMS 4667 IV NE—SERIES V874

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PATS BOTTOM QUADRANGLE
WYOMING—CARBON CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
NE/4 WALCOTT 15' QUADRANGLE

4668 II SW
(SCHNEIDER RIDGE)



Mapped, edited, and published by the Geological Survey

Control by USGS and USC&GS

Topography by photogrammetric methods from aerial photographs taken 1970. Field checked 1971

Projection and 10,000-foot grid ticks: Wyoming coordinate system, east central zone (transverse Mercator)
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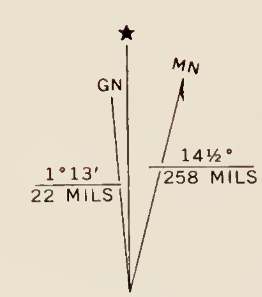
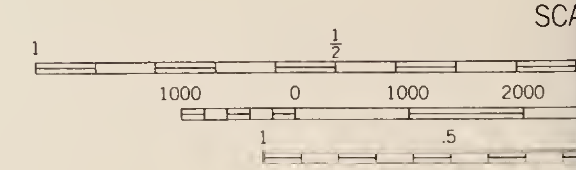


UTM GRID AND 1971 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

SCAL



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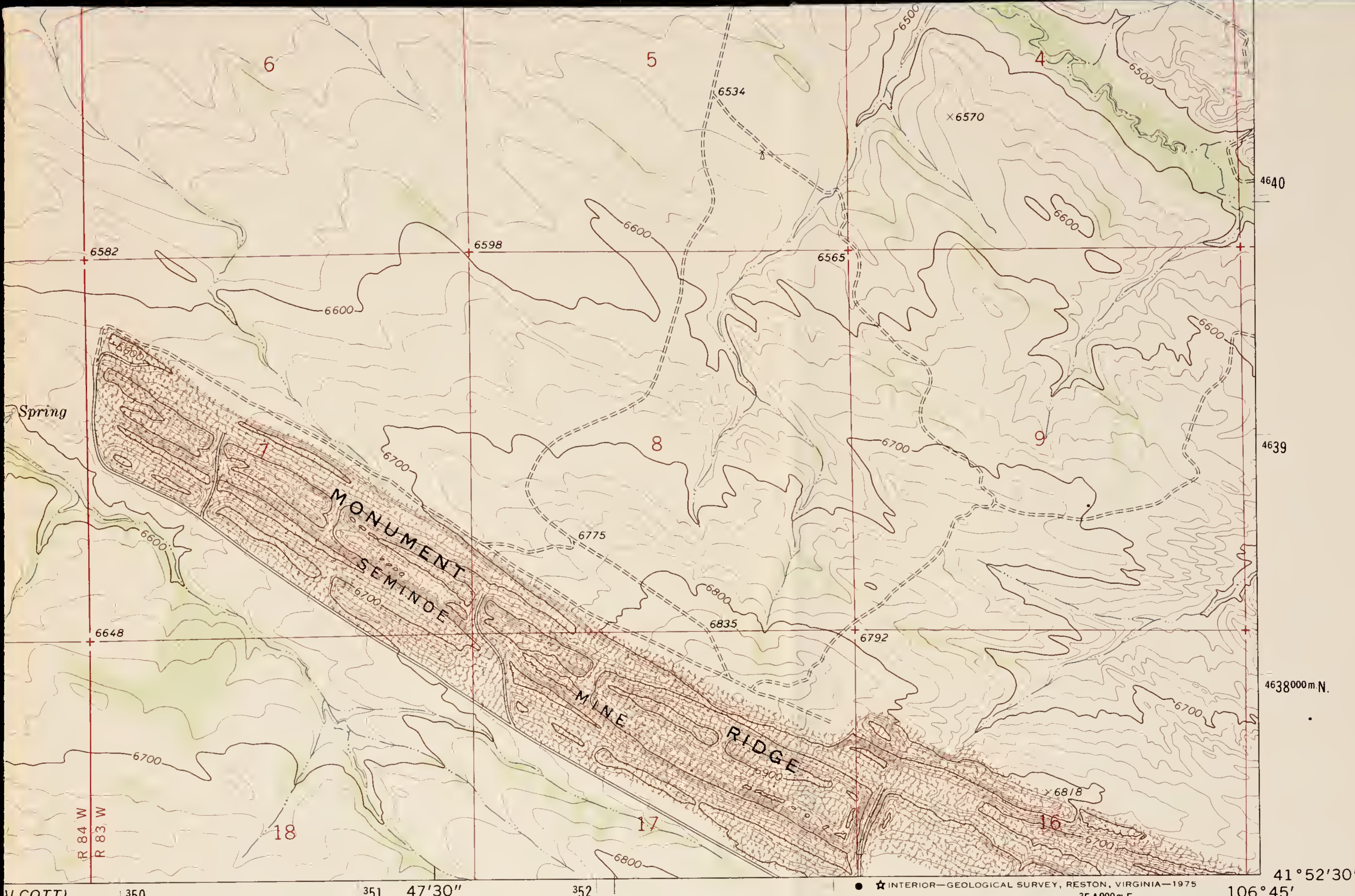

E 1:24 000

0 — 1 MILE

3000 4000 5000 6000 7000 FEET

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TERVAL 20 FEET
VERTICAL DATUM OF 1929

TIONAL MAP ACCURACY STANDARDS
ER, COLORADO 80225, OR RESTON, VIRGINIA 22092
PS AND SYMBOLS IS AVAILABLE ON REQUEST

WYOMING

QUADRANGLE LOCATION

ROAD CLASSIFICATION

Primary highway, hard surface

Light-duty road, hard or improved surface

Secondary highway, hard surface

Unimproved road

Interstate Route — U. S. Route — State Route

PATS BOTTOM, WYO.

NE/4 WALCOTT 15' QUADRANGLE
N4152.5—W10645/7.5

1971

AMS 4667 IV NE—SERIES V874